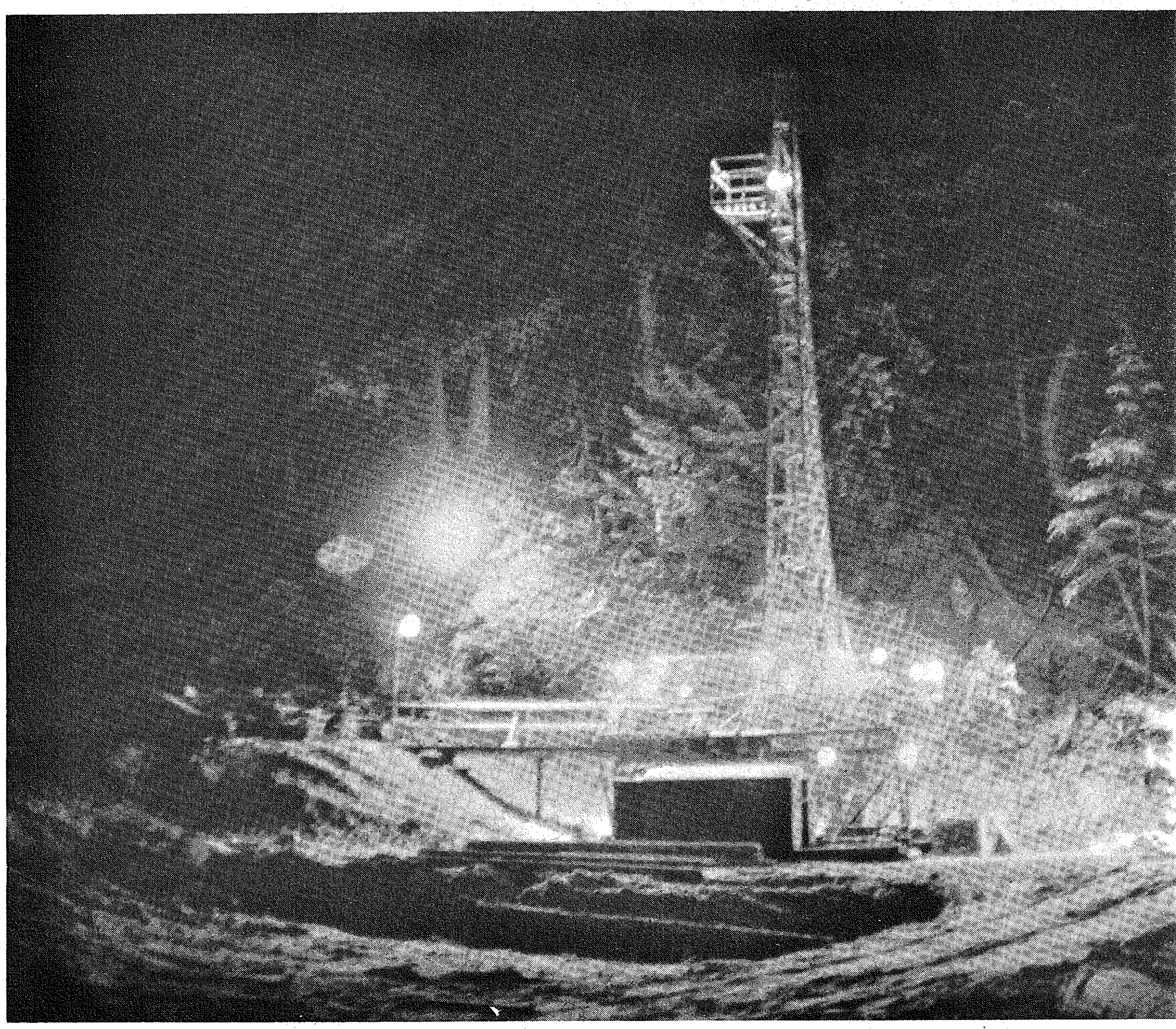
B.C. Hydro and Power Authority

Report on

1979 Drilling and Exploration Program
Meager Creek Geothermal Area
Upper Lillooet River, British Columbia

MARCH, 1980



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B.C. HYDRO AND POWER AUTHORITY

Report on

1979 DRILLING AND EXPLORATION PROGRAM
MEAGER CREEK GEOTHERMAL AREA
UPPER LILLOOET RIVER, BRITISH COLUMBIA

by

B.D. Fairbank, P.Eng.

J.F. Reader

T.L. Sadlier-Brown

MARCH 1980

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CONTRACT AUTHORIZATION

British Columbia Hydro and Power Authority
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COVER PHOTO

Diamond Drilling on night shift of drill hole M7-79D which reached a temperature of 202.2°C at 367 metres.

The high tower and elevated steel drilling platform were developed for geothermal drilling by the Construction Department of B.C. Hydro. The shed in the foreground houses the accummulator and back up controls for a blow-out preventor installed below the drilling platform.

Photo by T.L. Sadlier-Brown, November, 1979.

1.0 SUMMARY AND CONCLUSIONS

1.1 General

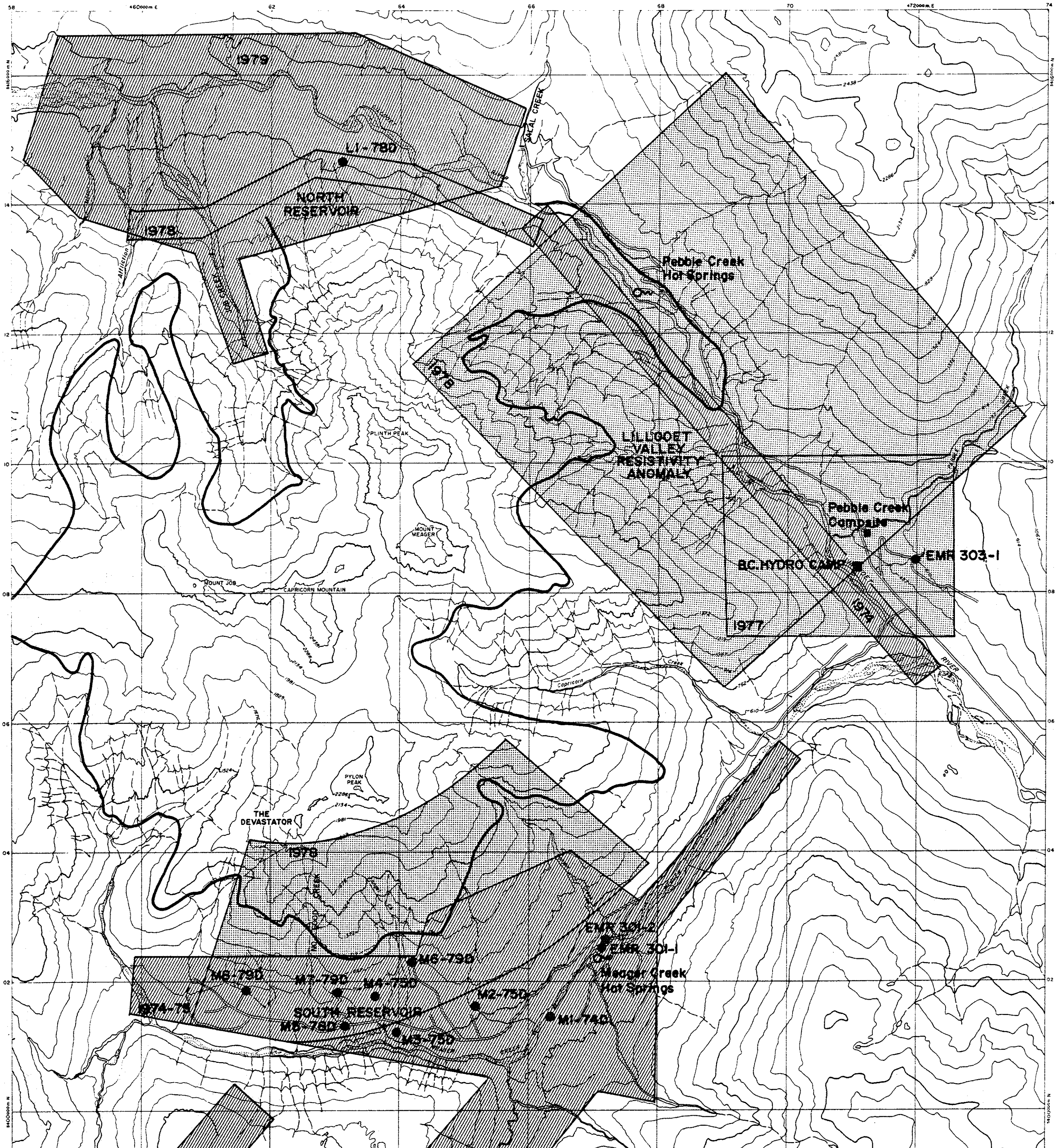
Results of 1979 exploration significantly enchance knowledge of the geothermal potential of the South and North Reservoirs. At the South Reservoir, drilling encountered temperatures in excess of 200°C at shallow depths. Resistivity anomalies located at the North Reservoir are attributed to geothermal water and present excellent drill targets.

The two areas are twelve kilometres apart on opposite flanks of the Meager Volcanic Complex (Figure 1.1). In both cases, geothermal waters occupy permeable fractures and faults within the crystalline and metamorphic basement complex. Leading exploration techniques are electrical resistivity surveys and temperature profiling in diamond drill holes supplemented by geologic mapping and modelling, water geochemistry, and self-potential (SP) surveys.

1.2 South Reservoir

Three drill holes, totalling 978 metres, were completed in the South Reservoir area in 1979. The highest temperature recorded was 202.2°C at 367 metres in hole M7-79D. Temperatures to 300°C within 800 metres of surface are inferred from extrapolated gradients. Reservoir host rocks are mainly quartz diorite and to a lesser extent, amphibolite. High porosity and permeability are indicated across faulted zones up to 20 metres wide.

Temperature results in wells drilled to date confirm the validity of the resistivity method in the Meager environment. The South Reservoir is estimated to enclose at least nine square kilometres. The reservoir terminates or deepens to the west across No Good Creek and to the northeast into the mountain above drill hole M6-79D. To the north, the reservoir continues toward Pylon Peak and the Devastator; the south boundary is open and unknown. The



LEGEND

RESISTIVITY COVERAGE

1978 — Pole-Pole method (Yr. of survey indicated)

1975 — Dipole-Dipole method (Yr. of survey indicated)

DIAMOND DRILLING COVERAGE

● Location and Well Designation

M6-79D

MEAGER VOLCANIC COMPLEX

Base of volcanic stratigraphy

Hot Springs

FIGURE 1.1

SUMMARY OF RESISTIVITY & DIAMOND DRILL COVERAGE

eastern margin of the reservoir ends in an outflow plume feeding the Meager Creek hot springs.

Untested, poorly resolved, low resistivity zones in the area of South Fork Creek indicate a possible southern extension of the South Reservoir as it is presently known. A South Fork Extension would more than double the accessible potential production area.

1.3 North Reservoir

Twenty-five line-kilometres of resistivity survey were completed over the North Reservoir area. Low apparent resistivities, capped by a thin resistive layer, form the main North Reservoir anomaly.

The anomaly is detected in the Job Creek Valley and on the northwest flank of Plinth Peak and appears to be centered under the north ridge of Plinth. It is open in all directions except the northwest into the Lillooet Valley. To the northeast, low resistivity zones become spotty and discontinuous. To the southeast, the main North Reservoir anomaly may connect with the western part of the Lillooet Valley Resistivity Anomaly (NSBG, 1978).

The North Reservoir anomaly is underlain by the quartz monzonite of the multiphase Fall Creek Stock and by older schist. Hole L1-78D, located near the margin of the resistivity anomaly, intersected quartz monzonite at 102.8^{o}C.

Three other single-line resistivity anomalies were detected on the north side of the Lillooet River. Their significance and relationship to the North Reservoir anomaly is presently unknown.

****

2.0 RECOMMENDATIONS

2.1 South Reservoir

Several areas within the South Reservoir require further definition. Proposed drill sites, listed in order of priority, are summarized below (refer to Figure 2.1):

Site 1) Located on quartz diorite outcrop on the north bank of Meager Creek to test the area on the south side of the Meager bench which is inferred to be hot. A hole here also tests the footwall of the Meager Valley south slope.

Site 2) Located to the east of M2-75D to define the eastern boundary of the South Reservoir.

Site 3) Well M8-79D intersected amphibolite and showed a slight improvement in temperature gradient at depth. Deepening of the hole would determine the nature of the temperature profile through the amphibolite-quartz diorite contact and Carbonate Fault system. Alternately, a shallower hole could be drilled to the east of M8-79D. This information is required as an aid in understanding the geothermal system, but it is of secondary importance in locating initial steam discovery wells.

Site 4) Located on the south fork of Meager Creek (South Fork Creek), to assess the possible South Fork Extension of the South Reservoir. This hole should be scheduled to follow preliminary mapping and additional resistivity. Road access is currently within one kilometre of the site.

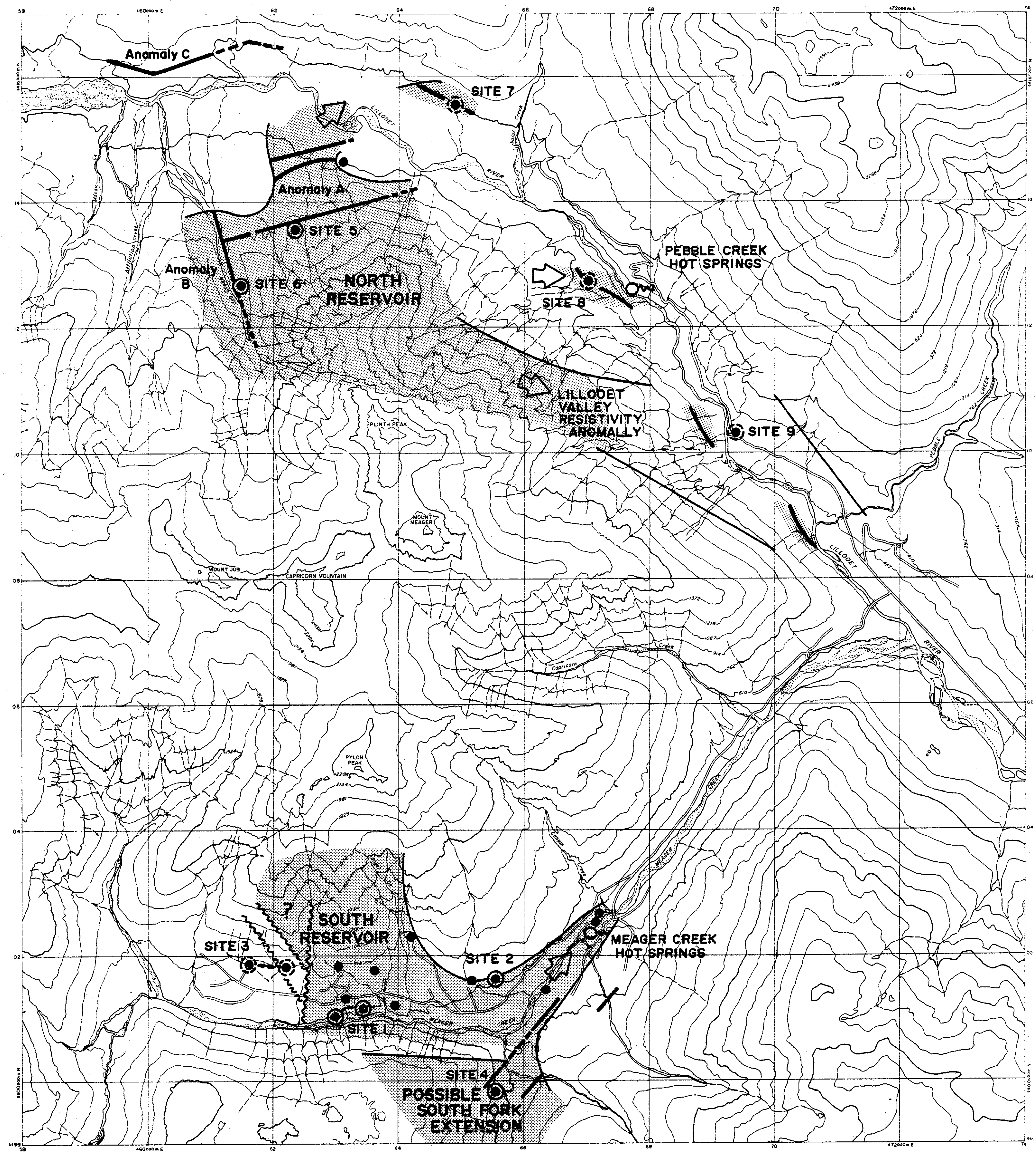
Additional recommendations are as follows:

1) A comprehensive structural study including fracture analysis of the South Reservoir and adjacent areas. Fracture patterns and relative intensity will affect the directions of thermal water migration and have a bearing on the shape and extent of the reservoir.

2) Mapping and resistivity surveys in the possible South Extension area to aid in locating an exploratory drill hole at site 4.
3) Continuing alteration and precipitate mineral studies of drill core.
4) A pilot program of geophysical well logging for orientation purposes and information on reservoir characteristics. Geophysical well logging techniques and interpretation programs used in the oil industry are designed for locating oil or gas reservoirs in layered, sedimentary strata. Although these techniques are also used in geothermal exploration and would be applied in future rotary holes at Meager Creek, new interpretation procedures may be required. Pilot survey results in a selected diamond drill hole would be compared with drill core and used as a basis for interpreting geophysical logs in future rotary drill holes.
5) Feasibility study of micro seismic exploration techniques to determine applicability in applied exploration at Meager Creek.

2.2 North Reservoir

The North Reservoir anomaly is a large target in a complex geological environment. The prime objective of 1980 work is to establish the relationship between low resistivity and high temperatures and to determine if and how resistivity response varies with basement rock type and other parameters. Anomaly A is underlain by quartz monzonite and Anomaly B mainly by schist, therefore, although they are continuous, they must be considered as separate targets. The following high priority drill sites are recommended (refer to Figure 2.1):



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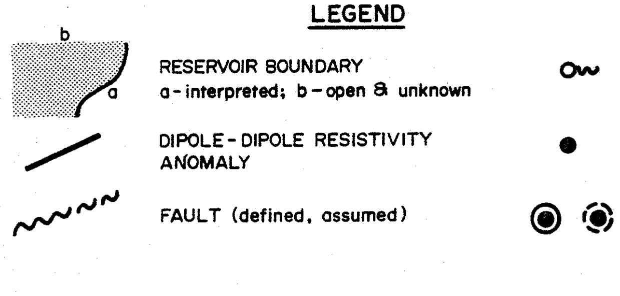


RESERVOIR BOUNDARY a - interpreted; b - open & unknown	HOT SPRINGS
DIPOLE-DIPOLE RESISTIVITY ANOMALY	EXISTING DRILL HOLE
FAULT (defined, assumed)	PROPOSED DRILL SITE priority 1, priority 2 (alternates shown with arrows)

FIGURE 2.1

SUMMARY OF RECOMMENDATIONS

Site 5) Located on the north flank of Plinth Peak, into a slight cupola in the low resistivity values where volcanic flows are thin, to test Anomaly A.

Site 6) Located at the eastern break-in-slope of the Job Creek Valley to test Anomaly B.

Additional drilling at the North Reservoir is dependent on positive results at sites 5 and 6 and should be scheduled to follow further resistivity surveys and mapping. The following sites designed to test possible lobes and connections to the main anomaly, are of second priority:

Site 7) West of Salal Creek to test moderately anomalous resistivity in the area.

Site 8) West of the Pebble Creek Hot Springs to test anomalous resistivity values (1974 survey) and assess their association with the hot springs. This site is only accessible by helicopter.

Site 9) Located 2 kilometres northwest of the Pebble Creek bridge to test the Lillooet Valley Resistivity Anomaly at an accessible point. A percussion drill hole here (1978) had a gradient of 57°C/km to 70 metres.

Resistivity anomalies north of the Lillooet River (Line Q) require further definition. Anomaly C (Appendix E-1) is of particular interest due to its layered, high-contrast, anomalous response. Groundwork should be directed at determining the cause of the anomalies and locating potential drill sites. A program of geological mapping and follow-up resistivity surveys should be implemented prior to drilling.

****

3.0 INTRODUCTION

3.1 Terms of Reference

Exploration at Meager Creek in 1979 was the sixth season of applied work toward the discovery of geothermal steam. The program implemented diamond drilling, geophysical and geological surveys recommended in the 1978 project report for B.C. Hydro and Power Authority and Energy Mines and Resources, Canada by Nevin Sadlier-Brown Goodbrand Ltd. (NSBG, 1979).

The Drilling Section of the Construction Division of B.C. Hydro carried out diamond drilling operations and managed base camp facilities.

Nevin Sadlier-Brown Goodbrand Ltd. was retained by B.C. Hydro as the prime engineering consultant to manage geological, geophysical, and certain road building work, and to obtain and interpret drill hole data. G.A. Shore of Premier Geophysics served as geophysical consultant for resistivity work.

3.2 Scope and Organization of Report

This report is a description of the activities and results of the 1979 field season at the Meager Creek Geothermal Project. Interpretations of new data and recommendations for future work are included. Descriptive data from past seasons are not repeated and the reader is referred to project reports for the years in question.

The two known geothermal systems (South and North Reservoir) are distinct from one another and at different stages of exploration. Although genetically similar, they have unique physical characterisitics and responses to applied exploration methods.

The report is thus organized by areas of exploration. The three main discussion sections are Reconnaissance and General Studies, South Reservoir, and North Reservoir.

The report employs a revised system for designating drill holes at Meager Creek (Appendix B-1).

3.3 Location and Access

The Meager Creek Geothermal Project area is located 160 kilometres north-northwest of Vancouver and approximately 60 kilometres northwest of Pemberton, B.C. (Figure 3.1). The area of geothermal interest is the Meager Volcanic Complex which lies between the Lillooet River and Meager Creek. Known temperature anomalies are the South Reservoir area, located on the north side of Meager Creek, and the North Reservoir area in the Upper Lillooet Valley.

Access to the project is via paved highway from Vancouver to about 20 kilometres northwest of Pemberton, continuing on good gravel-surfaced Forestry Development and private logging roads to the site. Access within the South Reservoir is by logging road while the North Reservoir is currently accessible only by helicopter.

3.4 Work Completed

The 1979 field season emphasized drilling in the South Reservoir and completion of resistivity surveying in the North Reservoir prior to drilling.

Three moderate-depth diamond drill holes were undertaken at the South Reservoir. Throughout the drilling program extensive downhole temperature measurements were taken in all holes. In addition, geology of parts of the South Reservoir was mapped and a VLF-EM survey performed to aid in more clearly defining structures in the area. Limited water sampling and geochemical analysis was done in hole M6-79D.

Work at the North Reservoir included control grid installation and a resistivity survey in the Upper Lillooet Valley. Geological mapping in the Job Creek Valley complemented the resistivity data.

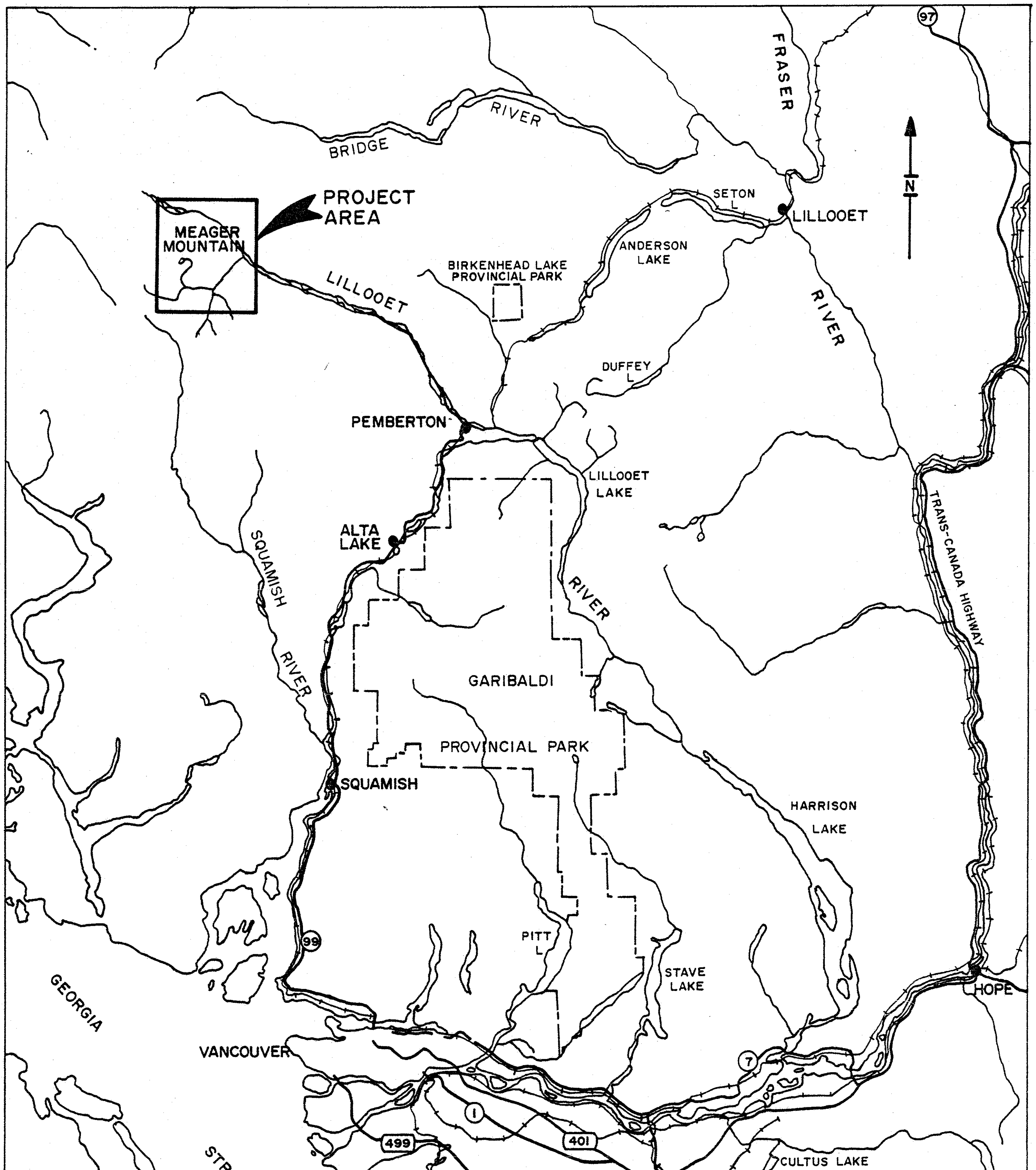


FIGURE 3.1

LOCATION MAP
MEAGER CREEK GEOTHERMAL
AREA

Reconnaissance work, covering the whole of the project area, included a basement-rock alteration study and aerial photography for colour stereographic photo coverage.

Construction of an access road leading to the North Reservoir was begun at the 26 mile marker on the Lillooet Forestry Development road and completed to Salal Creek for a total of 8 kilometres. Erection of the Salal Creek bridge began in November with cribbing completed and stringers launched before winter shutdown.

****

4.0 RECONNAISSANCE AND GENERAL STUDIES

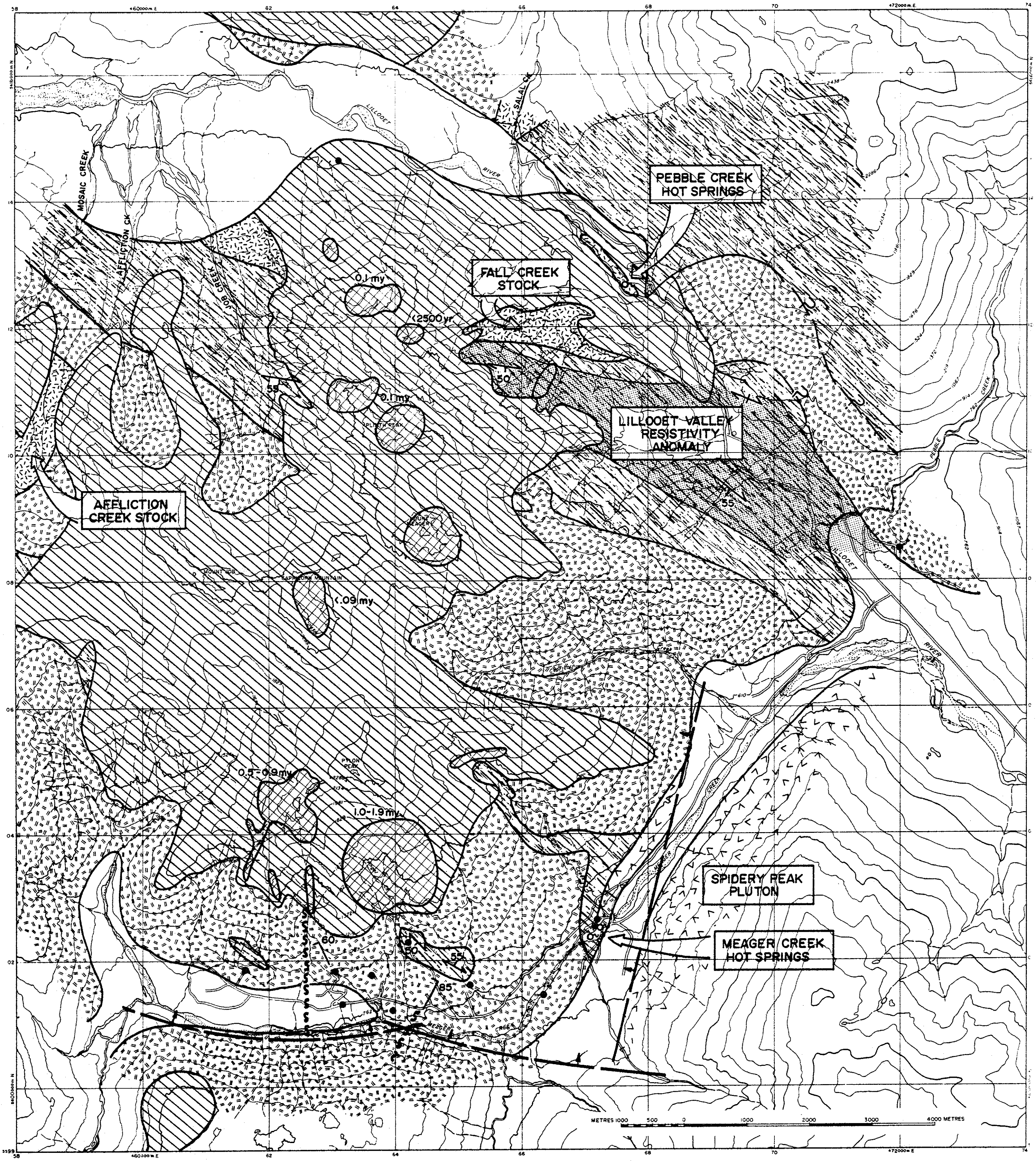
4.1 Geology of the Project Area

Geology of the Meager Creek Project Area has been described in detail in previous reports to B.C. Hydro by NSBG (1974, 1975, 1979) and by Read (1977, 1979), Souther (1975), Lewis and Souther (1978), Anderson (1975) and Woodsworth (1977). Only a brief description will be presented here as an introduction to current work. A summary plan of Project Area geology is presented in Figure 4.1.

The primary driving energy of the geothermal systems is related to the development of the Meager Volcanic Complex. Volcanic vents are the surface record of eruptions from molten magma at depth (10+km). Fossil magma chambers and the surrounding hot rock provide a heat source for contemporary geothermal systems through remnant heat dissipation. At Meager, eruptive centers lie along a 14-kilometre long north-south zone which bisects the complex.

The earliest (1.9 million years b.p.; Read, 1979) and probably most explosive episode of volcanism occurred on the south flank of the complex immediately north of current drilling in the Meager Creek Valley (South Reservoir). It is marked by an extensive basal breccia unit comprised of dominantly plutonic blocks, and overlying porphyritic andesite flows and breccia, porphyritic dacite flows and breccia, and hydrothermally altered rhyodacite tuff, flows, and breccia of the Devastator Assemblage. The high ratio of breccia to non-brecciated flow units indicates the explosive nature of the volcanism.

Successively younger volcanic stages, progressing south to north, are characterized by porphyritic andesite flows and breccia of the Plyon Assemblage, and porphyritic rhyodacite flows and breccia of the Devastation Glacier, Capricorn and Plinth Assemblages (Read, 1979). The latest event produced the Bridge River Ash and rhyodacite flows



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MEAGER VOLCANIC COMPLEX

Vent showing age (from K-Ar dates) in millions of years (Read, 1979).

QUATERNARY & TERTIARY – Rhyolite, rhyodacite and andesite flows, tuff and breccia.

BASEMENT COMPLEX

TERTIARY – FALL CREEK & AFFLICTION CREEK STOCKS – Biotite quartz monzonite, alaskite.

CRETACEOUS AND/OR JURASSIC – Variably foliated and altered quartz diorite and related plutonic rocks.

CRETACEOUS – SPIDERY PEAK PLUTON – Fresh biotite-hornblende quartz diorite.

TRIASSIC (?) – Metamorphic rocks including amphibolite, greenstone and phyllite.

Limit of outcrop or drill core data.

Geologic boundary

Normal fault (inferred), showing dip direction.

Fault

Fracture (inclined)

Foliation (inclined, vertical)

Diamond drill hole

Hot springs

Geology modified after Read, 1979.

FIGURE 4.1

SUMMARY OF GEOLOGY – MEAGER CREEK GEOTHERMAL AREA

exposed off the north-east flank of Meager Mountain and at the waterfalls on Lillooet River. These are less than 2500 years old. About half the bulk of volcanic rock is 100,000 years old or less.

The basement complex is comprised of northwest trending metamorphic rock and various types of plutonic rock. Weakly-foliated quartz diorite of Cretaceous age and related intrusions of the Coast Crystalline Belt are extensive in the project area, and comprise two-thirds of the basement. The quartz diorite contains roof pendants of older metamorphic phyllite, gneiss, amphibolite, schist and minor marble. Contact zones are commonly migmatite. An extensive metamorphic belt occurs in the Lillooet Valley and east flank of Meager Mountain, continuing under volcanic cover into the area of Job and Affliction Creeks. Other metamorphic outcrops are evident in Canyon Creek and immediately west of drill hole M6-79D in the Meager Creek Valley. Along the southeastern boundary of the project area, relatively fresh quartz diorite of the Upper Cretaceous forms the Spidery Peak Pluton.

Older plutons and metamorphic units were intruded in Miocene time by biotite quartz monzonite. Tertiary quartz monzonite occurs at Fall Creek (Silver Standard molybdenum prospect), in the Lillooet Valley downstream from the falls, above the bridge at Salal Creek canyon, in drill hole L1-78D, and in the area where Job Creek intersects the Lillooet Valley. These areas may in fact be parts of one large stock (Fall Creek Stock). Similar quartz monzonite occurs in the northwest of the project area at the headwaters of Affliction and Mosaic Creeks (Affliction Creek Stock).

Three styles of faulting have been recognized at Meager; those related to regional tectonic stress and failure, those related to volcanism (shattering by forceful emplacement of the volcanos and collapse faulting due to subsidence), and those related to mass creep and failure due to gravity. The former two styles may be important in localizing geothermal fluids. Tectonic faulting and jointing generally pre-date volcanism. Faults related to gravity are important to slope stability and are a consideration in the location of development facilities.

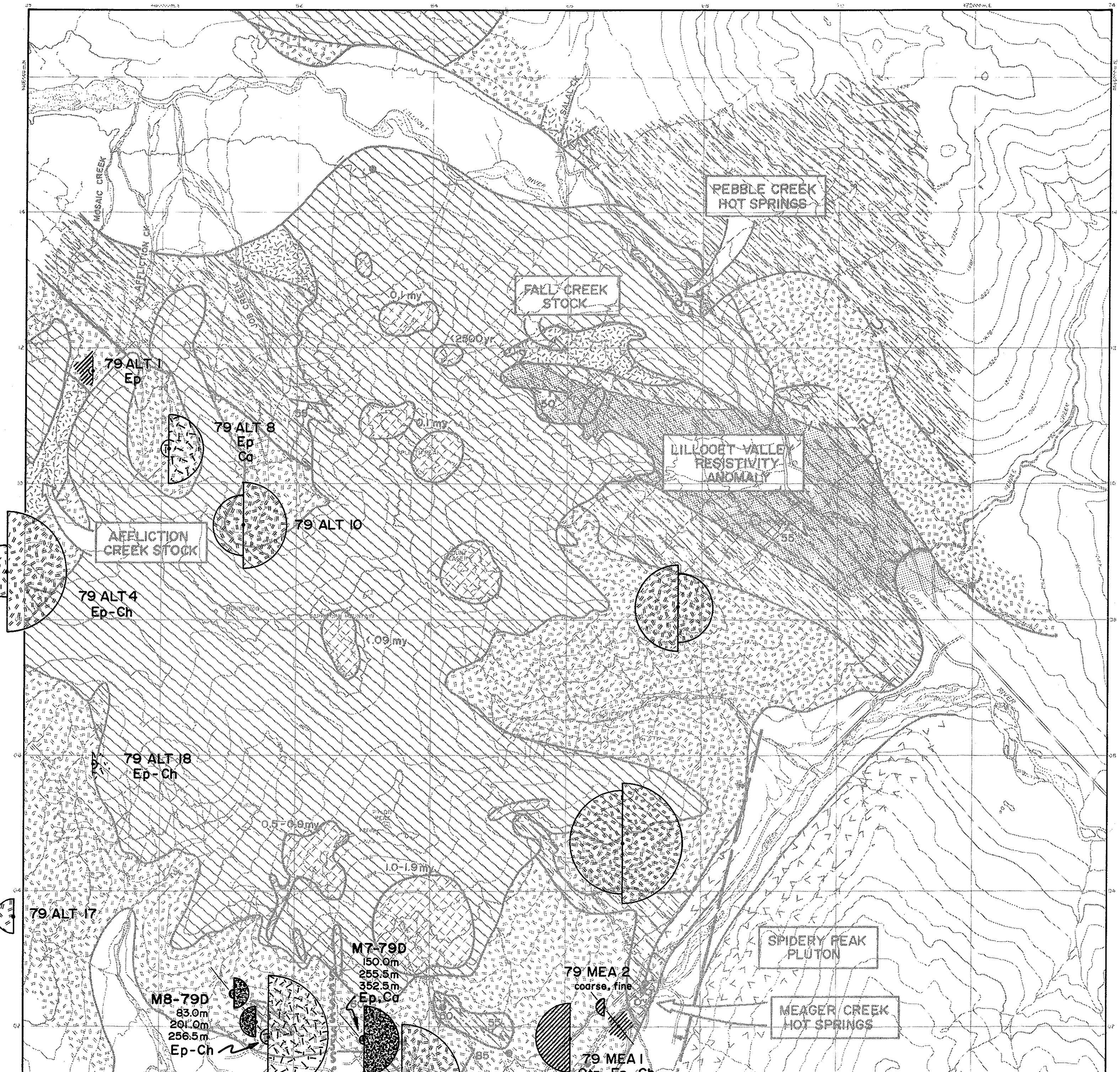
Evidence supports the existence of an early, steeply-inclined, north-south regional rift or fault zone, through the middle of the volcanic complex. Eruptive centers lie in a north-south pattern and temperature anomalies occur along the same regional trend.

4.2 Reconnaissance Alteration Study

A reconnaissance alteration study was conducted to determine if there is a hydrothermal alteration pattern associated with the inferred north-south structural zone or either of the North and South Reservoirs. Nineteen samples of Cretaceous biotite hornblende quartz diorite were collected with notes on fracture density and style at each site. An even sample distribution of similar basement rock type across the target features was attempted.

Thin sections and slabs for feldspar staining were cut and examined at Vancouver Petrographics Ltd. Parent and alteration minerals were identified, ranked numerically according to alteration intensity, and combined into two classes; 1) alteration of plagioclase and 2) alteration of mafics. A report by Dr. John Payne is contained in Appendix C-4.

Figure 4.2 is a plan map summarizing sample locations and alteration intensity. No large-scale alteration zone enveloping the hypothetical north-south structural zone is apparent. A small-scale alteration zone might be missed by the reconnaissance sample density. In addition, contact alteration from post-quartz



LEGEND

SAMPLE TYPE

- BIOTITE QUARTZ DIORITE
- BIOTITE HORNBLENDE QUARTZ DIORITE
- QUARTZ MONZONITE as above but contains patches with very fine-grained metamorphic (gneissic) textures.
- GNEISSIC QUARTZ DIORITE – sugary texture, mafics fresh. (Note that this rock is distinct from foliated quartz diorite)

ALTERATION RANK

8 7 6 5 4 3 2 1 — increasing intensity

ALTERATION CLASS

Alteration of Plagioclase (to sericite, epidote, calcite)

Alteration of Mafics (to chlorite, epidote)

VEINS – Types of veins present in section are noted following sample serial number.

FIGURE 4.2

PRELIMINARY ALTERATION STUDY MEAGER CREEK GEOTHERMAL AREA

diorite intrusions and local alteration effects may overprint the broader alteration pattern sought. However, no alteration aureole is discernable adjacent to Tertiary quartz monzonite stocks.

The South Reservoir is marked by a relatively high sericite/epidote ratio in altered plagioclase and by the presence of late calcite veins. Sericite indicates a higher grade of hydrothermal alteration proximal to the South Reservoir compared with regional propylitic alteration. Also of note is the lack of chloritization of biotite in some samples (eg: 79MEA1, 79MEA2, 79ALT 16). Here, the biotite itself does not appear to be high-grade potassic secondary mineralization; rather, it appears as well-developed coarse crystals, pleochroic in greens (thin section). Late calcite veins, seen also in drill core, are present in samples from the South Reservoir area. In contrast, epidote (± chlorite) veins are widespread, and are related in origin to the pervasive epidote-chlorite alteration of mafic minerals. The high sericite/epidote ratio and preponderance of calcite veining associated with the South Reservoir could be used in geothermal prospecting elsewhere in the project area.

Quartz diorite at the North Reservoir is largely overlain by volcanic flows making sample collection difficult. No conclusions can be reached regarding the alteration effects of the North Reservoir because of the poor sample density. A better distribution of sample locations will be possible with road access to the area planned in 1980.

The most striking aspect of the hydrothermal alteration is its apparent relationship to rock type. The quartz diorite samples were divided into four sub-types; 1) biotite quartz diorite, 2) biotite hornblende quartz diorite (and minor diorite), 3) quartz diorite with patches of fine-grained metamorphic textures and 4) gneissic quartz diorite. There is a progressive decrease in alteration, especially of mafic minerals, through the series from 1 to 4. Also, there is a concentration of samples with gneissic texture (sub-types 3 and 4) in the southern part of the project area. Gneissic quartz diorite (sub-type 4) is distinctly different from the variably-foliated quartz diorite (sub-types 1 and 2) which is more prevalent in the region (refer to Appendix C-4). It is probable that the relatively fresh gneissic quartz diorite is a contact metamorphic effect of the Spidery Peak Pluton and therefore has had a shorter alteration history than the quartz diorite.

****

5.0 SOUTH RESERVOIR

5.1 Exploration Synopsis

The South Reservoir was confirmed in 1975 by preliminary drilling, resistivity, and geochemical work. An anomalous, low apparent-resistivity zone within the basement complex detected by dipole-dipole surveys in 1974 and 1975 and by a pole-pole survey in 1978, is attributed to hot, subsurface geothermal solutions. Prior to 1979, the main thermal zone on the Meager "bench area" was indicated by four shallow diamond drill holes. The deepest hole into bedrock was 91 metres (M2-75D), maximum recorded temperature was 103.7^{o}C (M5-78D), and the highest gradient was 365^{o}C/km (M3-75D).

The 1979 exploration program had three main objectives: 1) to obtain deeper temperature data for a more complete interpretation of the deep thermal regime, 2) to determine the most promising site for the initial deep well into the potential production zone, and 3) to confirm the interpreted west boundary of the main reservoir, coincident with the sharp resistivity cut-off at No Good Creek. Drilling was the main exploration method, supplemented by surface mapping. Three holes were completed with very encouraging results. The best hole had a conductive temperature gradient in excess of 1000^{o}C/km above the first indications of circulating geothermal fluid at 233 metres, and reached a maximum temperature of 202.2^{o}C at 367 metres total depth.

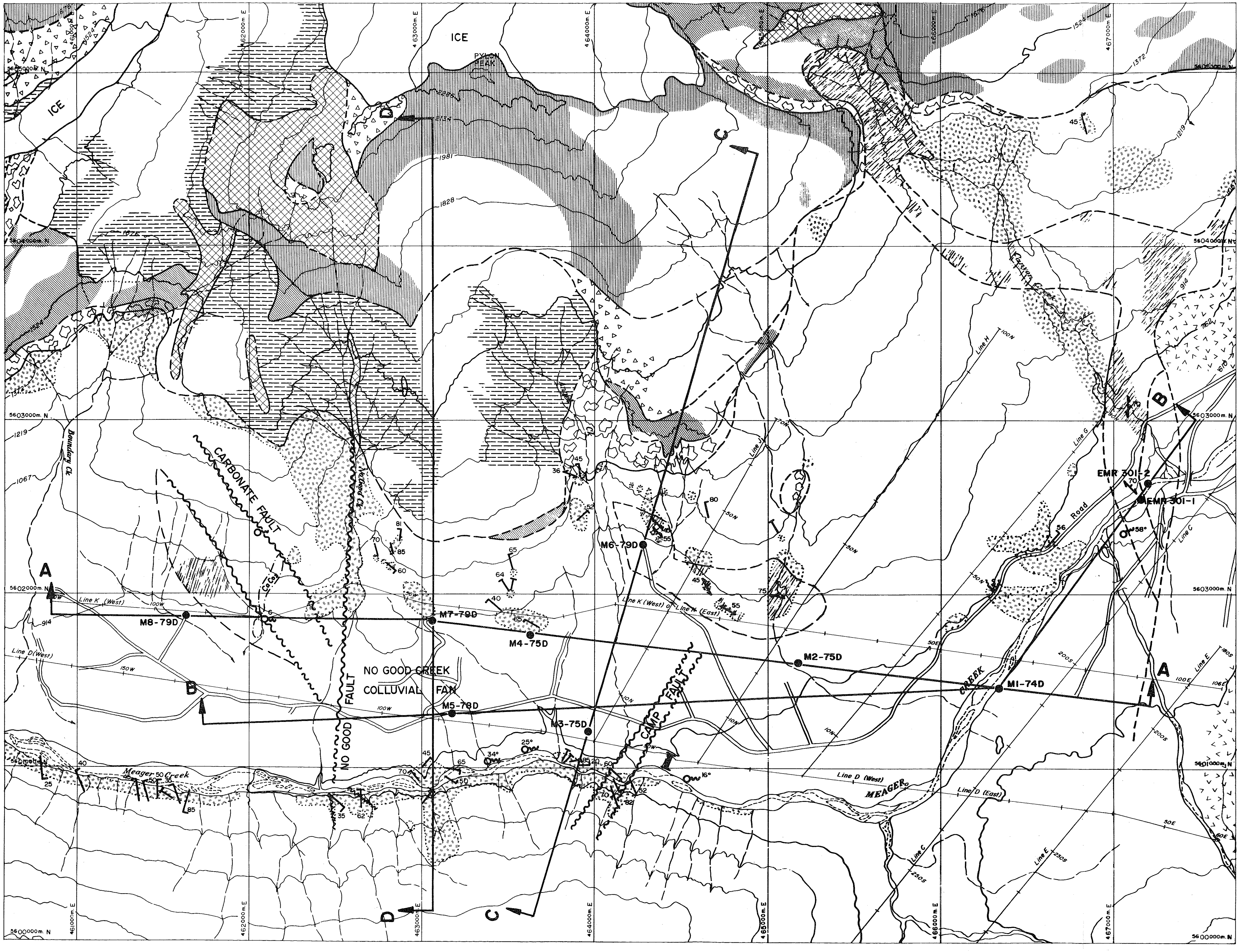
5.2 Geologic Mapping

Geologic mapping was done in the Meager Valley to augment drill core logs and earlier mapping at higher elevations by Read (1979). Mapping was concentrated on basement rock exposures along Meager Creek, and above the break-in-slope on the north side of the valley. Additional work was done on the surficial geology of the Meager Creek Valley (refer to Section 5.4).

Figure 5.1 is a geologic map of the South Reservoir area after Read (1979) and incorporating work by NSBG. Only the current study of basement geology is discussed below since basement rocks and structures host and control the configuration of the South Reservoir.

In the South Reservoir area, variably-foliated and altered biotite (hornblende) quartz diorite predominates. The quartz diorite contains tabular and wedge-shaped pendants of banded amphibolite and quartzofeldspathic gneiss up to 300 metres thick. Metamorphic pendants are intersected in drill holes M8-79D and M6-79D, and outcrop east of M6-79D and at Canyon Creek. Intrusive contacts are gradational through migmatite zones of mixed quartz diorite, gneiss, and amphibolite. Internal foliation of the quartz diorite is sub-parallel to intrusive contacts and conformable with amphibolite foliation and banding.

Quartz diorite of the Spidery Peak Pluton (Read, 1979) at the east margin of the map area, is distinguished from earlier quartz diorite by its equigranular granitic texture (hypidiomorphic-granular) and relative freshness. Adjacent to the pluton, sugary-textured (saccharoidal), dioritic, biotite quartz feldspar gneiss probably reflects contact metamorphism. The gneiss, undifferentiated from foliated quartz diorite in Figure 5.1, occurs in drill hole M1-74D, at road cuts north of M1-74D, and at Meager Creek exposures northeast of M1-74D below the road cuts. The freshness of the Spidery Peak quartz diorite and related gneiss, compared to the variably-foliated, altered quartz diorite, is due to its shorter alteration history.



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MEAGER VOLCANIC COMPLEX

QUATERNARY

- VENT AREA

PYLON ASSEMBLAGE

- ANDESITE PORPHYRY FLOWS
- ANDESITE PORPHYRY BRECCIA

DEVASTATOR ASSEMBLAGE

- ALTERED RHYODACITE FLOWS
- PORPHYRITIC DACITE FLOWS
- BASAL BRECCIA; PLUTONIC BLOCKS

BASEMENT COMPLEX

CRETACEOUS

- SPIDERY PEAK QUARTZ DIORITE

CRETACEOUS and/or JURASSIC

- QUARTZ DIORITE

TRIASSIC

- AMPHIBOLITE, GNEISS, MIGMATITE

- AREA OF OUTCROP
- GEOLOGIC BOUNDARY (defined, assumed)
- FAULT (defined, assumed)
- 25 FRACTURE (inclined, vertical)
- 50 FOLIATION (inclined, vertical)
- DIAMOND DRILL HOLE
- 25° C SPRING (hot, cold)
- SECTION LOCATION
- MEASURED SECTION OF SURFICIAL GEOLOGY (See Fig. 5.6)

Geology modified after Read, 1979.
Includes mapping by NSBG.

FIGURE 5.1

GEOLOGY AND LOCATION KEY SOUTH RESERVOIR

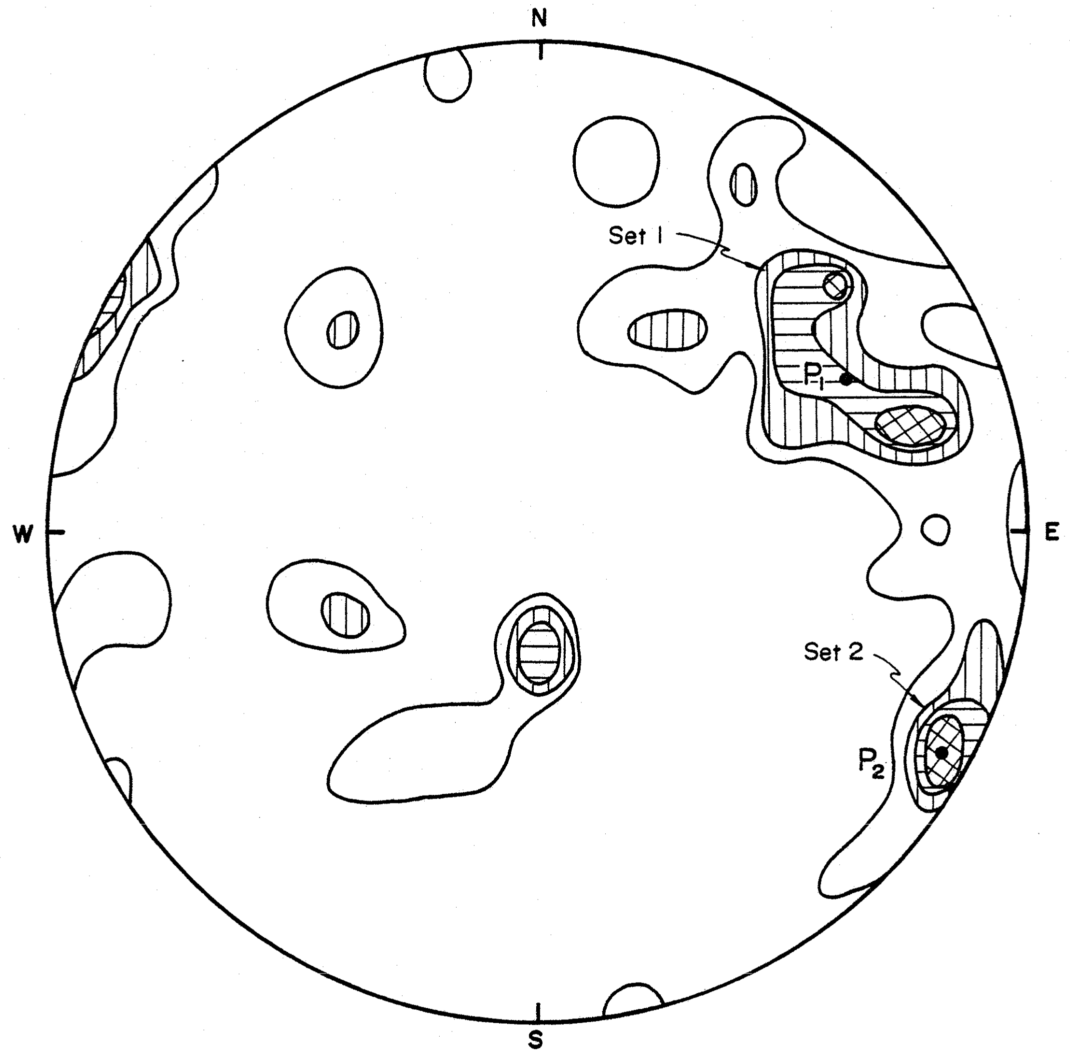
A variety of young subvolcanic dykes, correlated to the Pylon and Devastator Assemblages, transect all other rock units. The most common lithologies are light green, dacitic feldspar porphyry and milky-white, aphanitic rhyolite.

Two stages of hydrothermal alteration are recognized. An early stage affects the variably-foliated quartz diorites and metamorphic rocks. It is marked by 1) pervasive propylitic (chlorite, epidote, carbonate and albite) alteration 2) local silicification resulting in a fine-grained mosaic of interlocking anhedral quartz grains, and 3) flooding and healing of old fractures by fine-grained epidote - quartz "veins".

A late stage clay-carbonate-quartz-chlorite alteration partially obscures original textures of hypabyssal dykes. Permeable fault zones are commonly marked by moderate to complete alteration to soft clay. Clay-carbonate and silica veins and precipitates on fractures cut all rock types and other alteration assemblages.

An interpreted fault predating the emplacement of the Meager Volcanics is named No Good Fault on Figure 5.1. Its existence is suggested by EM surveys in 1979 which showed anomalies on five lines at points coincident with No Good Creek (Appendix D-2) and, perhaps more importantly, by changes in resistivity response and subsurface temperatures.

The existence of a relatively young, east-west subsidence fault(s) along Meager Creek, dipping towards explosive eruptive centers at the Devastator and in Angel Creek is tentative. It is premised on the fact that the south wall of the Meager Valley is physiographically immature and may be a dip slope on the fault surface. The fault has not been penetrated by drilling except



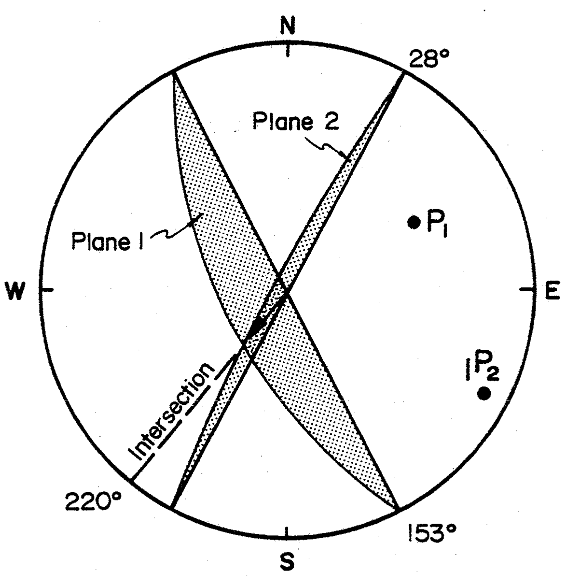
FORTY-FOUR POLES TO FRACTURE ATTITUDES PLOTTED

Contoured in percent of total sample.

- 2-4 %
- 4-6 %
- 6-8 %
- 8-10%

- P_1 Pole to mean attitude of fracture set 1.
- P_2 Pole to mean attitude of fracture set 2.

LOWER HEMISPHERE EQUAL AREA PROJECTION
(Schmidt Net)



LOWER HEMISPHERE STEREOGRAPHIC PROJECTION
(Wolff Net)

PLANE 1 – (Mean attitude of fracture set 1)
strike 153°, dip 60°SW.

PLANE 2 – (Mean attitude of fracture set 2)
strike 28°, dip 84°NW.

INTERSECTION OF PLANES 1 & 2.
bearing 220°, plunge 58°.

FIGURE 5.2

FRACTURE ATTITUDES SOUTH RESERVOIR

possibly by M3-75D where geologic logs indicate disrupted bedrock at depth.

Faults occur at the carbonate springs (Carbonate Fault) dipping away from the reservoir, and in Meager Creek northeast of M3-75D (Camp Fault). The Carbonate Fault probably controls the flow of cool water to the carbonate springs. The Carbonate Fault and faulted, broken amphibolite in the hanging wall (M8-79D) may be of critical importance with regard to cool water migration near the west margin of the near-surface part of the hot reservoir. The significance of the Camp Fault is unknown.

Fractures measured in the area between No Good Creek and the Meager Creek main hot springs are shown in projections on Figure 5.2. The results show two dominant fracture orientations ($153^{o}/60^{o}$SW and $28^{o}/84^{o}$NW) within the known reservoir area. The attitudes of the two main fracture sets are consistent with regional tectonic lineaments rather than with expected fracture attitudes related to volcano subsidence.

5.3 Drilling

5.3.1 Introduction

Three holes, each with a specific purpose, were drilled at the South Reservoir. M6-79D and M7-79D are into the main low resistivity zone while M8-79D is beyond the western limit of the anomaly.

Drilling was done by B.C. Hydro with two drills. A modified Boyles 56A diamond drill used an 18 metre high mast and elevated steel platform which were custom-designed and constructed by Hydro to allow installation of a 3000 psi Shaffer blow-out preventor (BOP) stack and rotating head. The modified rig was used for holes M6-79D and M7-79D, where temperatures in excess of 100°C were expected. A Boyles 37A, without BOP equipment, was used to drill M8-79D in which temperatures below 100°C were predicted. All holes were cored with H equipment giving a 9.6 cm bore and 6.3 cm diameter core. Mud was used in the drilling fluid and was generally recirculated.

Hole M7-79D is lined with 2 inch pipe with the bottom 55 metres perforated. Hole M6-79D was cemented in and abandoned and M8-79D was left unlined with casing in place in anticipation of deepening it in 1980.

5.3.2 Engineering Methods

Data obtained from drill holes included daily bottom-hole temperatures and standing water levels, post-drilling temperature profiles and core geology. Core was logged for lithology, structure, fracture density, alteration, precipitated minerals and rock competency. Return water temperature was continually monitored as a safety precaution. Drilling proceeded as long as downhole temperatures remained within established limits defined by the proximity of the temperature profile to the boiling point curve.

The primary downhole temperature measurement system was a Kuster Amerada-type probe run in the hole with an oilfield wireline winch unit. Various mercury-filled Bourdon-tube thermometer elements allowed temperature measurements from 0°C to 250°C. Higher temperature range elements were available on demand. The Kuster probe is a self-contained downhole system employing a clock-run chart recorder attached to the temperature element. This integrated probe is lowered into the hole with high strength, corrosion resistant, stainless steel wireline.

A second downhole measurement unit was a thermistor type, limited to temperatures less than 150^{o}C and to depths less than 200 metres. The thermistor probe enabled measurement of temperatures while two holes were being drilled in the South Reservoir simultaneously.

A maximum-registering mercury thermometer was used as a back-up measuring method. The maximum-registering thermometer was employed as a check on the Kuster unit and the thermistor unit, and when higher temperature range Kuster elements were not onsite. The thermometer was lowered in the hole either within a downhole water sampler or strapped to the outside of the normal dowhhole instrument.

Experience has shown that eight hours static time is generally sufficient for measured temperatures to rebound to within two or three degress of true equilibrium (See Appendix B-9). Bottom hole temperatures (BHT's) were measured following a suitable period during which no drill fluid was circulated, usually between the afternoon shift and the following morning shift. Detailed post-drilling traverses were run periodically during drilling and after holes were completed.

Past experience at Meager and elsewhere (NSBG, 1975; White, 1975; Lewis, 1977; Lewis and Souther, 1978) indicates that bottom-hole temperatures, obtained as drilling proceeds,are a more reliable estimate of pre-existing undisturbed rock temperatures than the off-bottom post-drilling measurements. The hole itself can short circuit fracture-acquifers and temperatures are then affected by convection and cross-flows in the hole. Post-drilling measurements are generally more detailed however, and serve to aid in the interpretation of and location of the dominant flow zones.

The temperature of return drill fluids was monitored with a thermistor probe thermometer and a portable battery-powered chart recorder. Measurements were calibrated with a mercury thermometer and compared with the temperature of intake fluid to determine the incremental increase in temperature while the fluids circulated in the hole. The highest return water temperatures reached 23°C when BHT's were 130-140°C in hole M7-79D.

The geology, alteration, precipitated minerals, and fracture density were logged. Logs are presented in Appendices B-4,-5, and -6. The system used to gauge fracture density was the Rock Quality Designation system (RQD). The RQD presents the cumulative length of unbroken core fragments over 10 cm in length as a decimal fraction of the recovered core and thus effects a qualitative estimate of fracture density, competence and porosity.

5.3.3 Summary of Well M6-79D (Total Depth - 321.0 metres)

Well M6-79D is located just east of Angel Creek at the break-in-slope northward of all previous drilling (Figure 5.1). It tests the northeastern part of the anomalous resistivity zone, and it is in close proximity to the lowermost exposures of a thick sequence of basal breccia (a possible deep-rooted aquifer).

Figure 5.3 shows a graphic log of the core, comprised mainly of quartzofeldspathic gneiss and banded amphibolite. Locally, the gneiss grades into biotite (hornblende) quartz diorite. Foliation is generally about forty-five degrees to the core axis, consistent with foliation attitudes of metamorphic outcrops immediately northeast of the hole. Metamorphic rocks are cut by altered creamy-white rhyolitic dykes and light green, dacitic, feldspar porphyry dykes, correlated by Read (Appendix C-2) to the volcanic Devastator Assemblage. The dykes are intrusive along

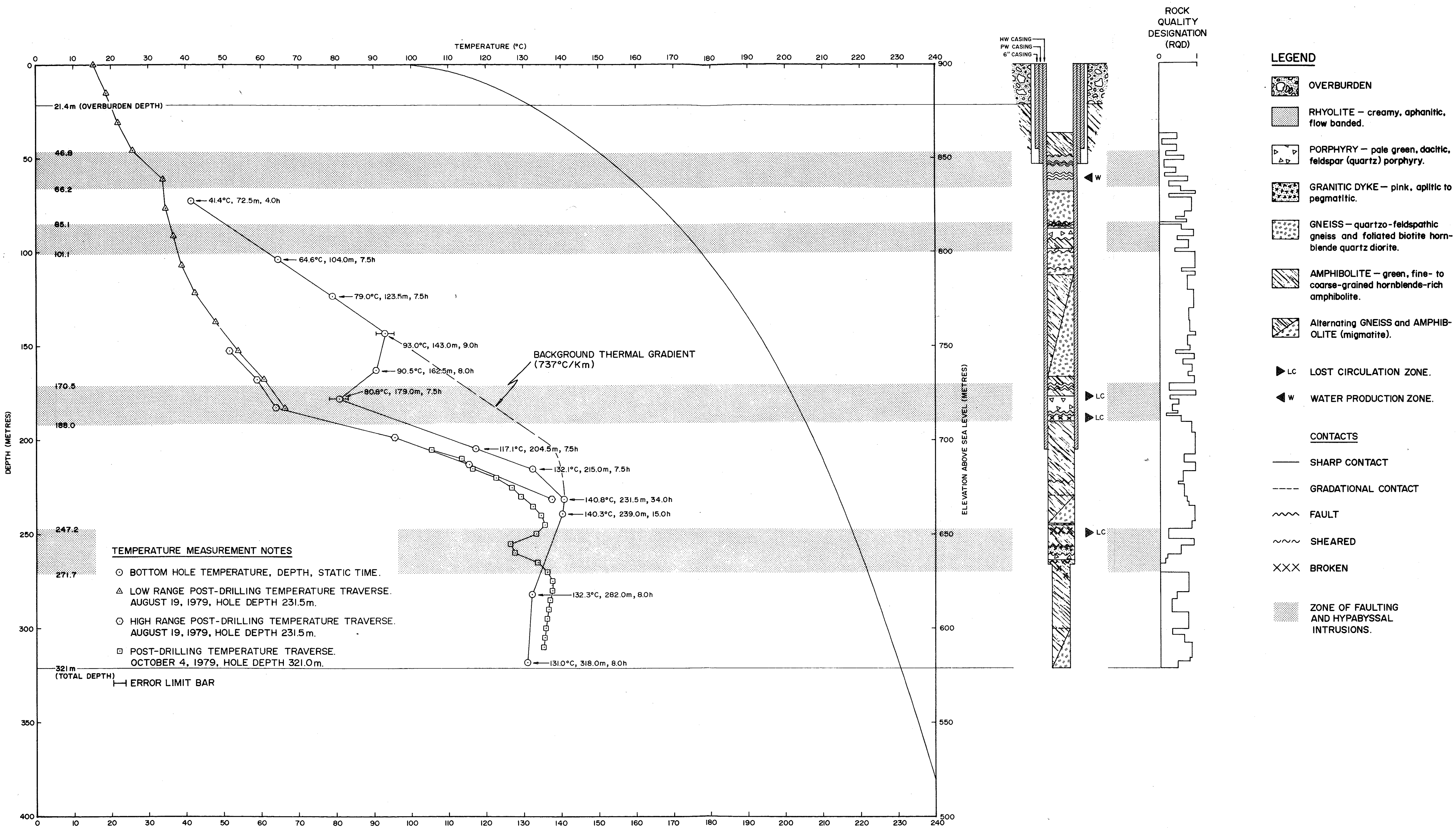


FIGURE 5.3

TEMPERATURE PROFILE AND GRAPHIC LOG RESEARCH WELL M6-79D (79-H-I)

faults, some of which display post-dyke fault movement. Similar dykes have been mapped on surface to the northwest of the drill hole. Faults and dykes are contained in discrete zones of poor rock quality which, as discussed below, correspond to subsurface water migration zones.

Mafic minerals in the metamorphic rocks, particularly the amphibolite, are variably altered to chlorite, epidote, and calcite. Hypabyssal dykes, permeable fault zones, and enclosing rocks are strongly altered to clay ("kaolinite", "montmorillonite" and/or "illite"), carbonate (calcite, dolomite), and local albite and quartz (Read, Appendix C-2). The clay-carbonate alteration is in part contemporaneous with hydrothermal alteration of the Devastator Assemblage (1.0 - 1.0 m.y.) and may also be associated with the present-day geothermal system.

The youngest hydrothermal minerals are carbonate, quartz-carbonate, and lesser quartz (silica) occurring as veinlets and fracture precipitates cutting all other lithologies and alteration. Carbonate and minor silica precipitates are present throughout the core but rarely do they completely fill or seal fractures.

Figure 5.3 shows the bottom-hole temperature (BHT) profile and several post-drilling temperature profiles. Hole M6-79D reached a maximum of 140.8^{o}C at 231 metres. The deepest temperature was 131^{o}C at 318.0 metres. The upper part of the bottom-hole temperature profile displays a conductive thermal gradient of 737^{o}C/km. This is followed by a small-scale temperature inversion and recovery interpreted as laterally flowing, relatively cool water in the permeable interval between 170.5 and 188.0 metres. Lower temperatures associated with the lateral flow are superimposed on the more regional, or "background", conductive thermal gradient. In the bottom section of the hole, the profile displays a second inversion and becomes nearly isothermal. The broad scale of the lower inversion indicates that it derives from a large-scale convective heat flow or lateral heat conduction rather than a discrete hot or cold water flow. Since higher temperatures are recorded from other parts of the South Reservoir, the hole is probably near the edge, rather than at the center, of a convection cell (where vertically moving water would produce an isothermal gradient). It is possible that the broad inversion represents only an upper tier of convection and that temperatures increase at greater depth. The hole was terminated at 321 metres due to difficult drilling conditions, precluding a definitive interpretation of the deeper temperature fluctuations.

Post-drilling temperature traverses were run on two different dates. The upper two post-drilling traverses, graphed on Figure 5.3, were run inside the rods, 36 hours after the last drill fluid circulation, with the hole at 231.5 metres depth. At that time, the observed BHT conductive gradient between 72 and 143 metres was no longer apparent and post-drilling temperatures had fallen off as much as 43^{o}C. The temperature decrease is attributed to relatively cool water which flowed into the hole at 55.5 - 58.6 metres (a water production zone), down the outside of the drill rods, and back out into bedrock between 170.5 and 188.0 metres (a lost circulation zone). The slow moving water was heated gradually by the enclosing hot rock. The alternate case of a flow of relatively cool water up the hole between the same two acquifers is discounted because the post-drilling curve does not show the water to be heated in passage by the relatively hot enclosing rock.

A third post-drilling traverse was done in the bottom section of hole when the depth was 321 metres 20 hours after last circulation. It indicates a relatively cold, lateral water flow, not detected by bottom-hole measurements, between 247.2 and 271.7 metres. Temperatures near the bottom of the hole had risen 4^{o}C above corresponding BHT measurements with the additional 12 hours equilibration time.

5.3.4 Summary of Well M7-79D (Total Depth - 367.0 metres)

Well M7-79D, east of No Good Creek at the break-in-slope of the Meager Valley, was designed to assess the strong western part of the resistivity anomaly at a point up-slope from 100^{o}C water in overburden (Figure 5.1).

The hole is entirely within medium-grained, variably-foliated quartz diorite (Figure 5.4). The quartz diorite is cut by numerous fault zones, and intruded by strongly-altered, light green, porphyritic dacite, aphanitic dacite, and flow-banded rhyolite, hypabyssal to the Devastator Assemblage. As in hole M6-79D, the volcanic dykes are intrusive along fault zones.

Rock competency is poor in the upper cased section where drill circulation was lost to shattered quartz diorite, in discrete intervals of faulting and dykes, and in certain altered sections toward bottom that appear to be currently-active, hot water migration zones.

Pervasive, weak, propylitic alteration (chlorite, epidote, calcite) and local silicification are an early stage of alteration of the quartz diorite. Dacite dykes, fault zones, and enclosing rocks are intensely altered to clay and carbonate minerals, sometimes completely destroying original textures. This alteration has the same character as that described in hole M6-79D and is genetically associated with the Devastator Assemblage and/or the

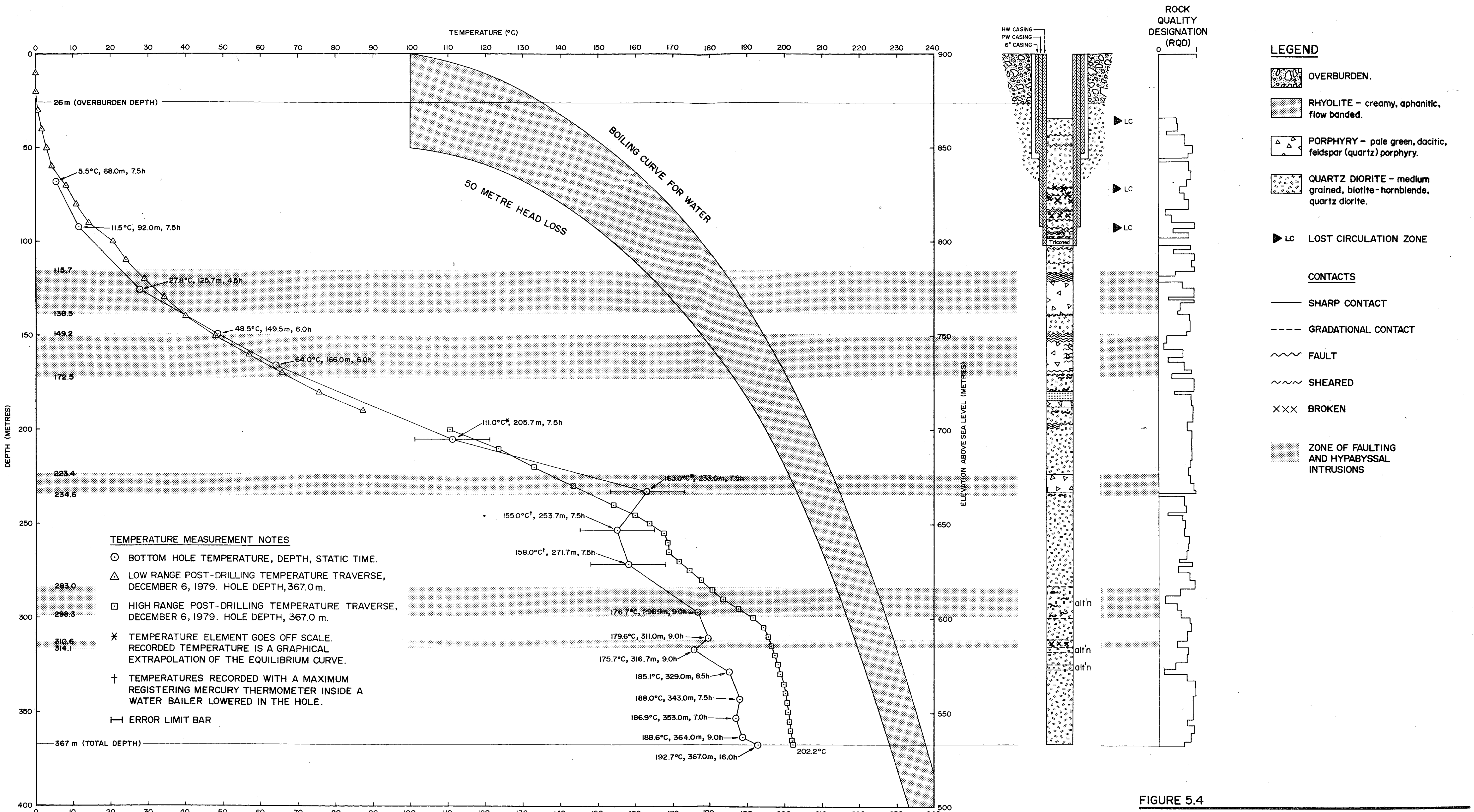


FIGURE 5.4

TEMPERATURE PROFILE AND GRAPHIC LOG RESEARCH WELL M7-79D (79-H-2)

present-day geothermal system. Strong propylitic (chlorite, calcite) alteration of quartz diorite between 283.0 and 298.5 metres is due to hot water migrating through that interval.

Iron oxide from surface weathering is pervasive on fractures to 122 metres. Carbonate veins and precipitates are common throughout the hole. Silica precipitates are subordinate to carbonate, occurring mainly at depths greater than 200 metres. Ilmenite is present in quartz veins at 261.5 and 262 metres. Finally, a white scaley precipitate in the bottom 40 metres is calcareous with an unidentified soft component (clay?). Fractures are rarely filled or sealed with precipitate and, in fact, open fractures are clean in some sections.

Well M7-79D recorded the highest bottom-hole temperatures (192.7^{o}C) and thermal gradients (greater than 1400^{o}C/km) to date. Post-drilling temperatures reached 202.2^{o}C.

The bottom-hole temperature profile consists of two parts; an upper segment from near surface to 233.0 metres, characterized by conductive upward heat flow, and a lower segment characterized by convective heat flow accompanied by an overall decrease in temperature gradient. The conductive upper section of the thermal regime is suppressed by cold surface water, circulating to approximately 175 metres dpeth, giving rise to the observed gradually increasing temperature gradient with depth.

The inflection point of the BHT curve represents the upper limit of geothermal fluids. It coincides with the broken lower contact of a porphyry dyke and with a change from good to variable rock quality.

The lower part of the BHT curve has an average temperature gradient of about 225°C/km. Fluctuations in the curve signify water movement in the rock. These are probably low-pressure, low-flow water zones since no changes in the drill fluid return flow or equilibrated standing water level (-50 metres) were noted through the section.

The post-drilling profile agrees with the BHT profile fairly well in its upper part. Where geothermal fluids are suspected in the lower part of the hole, the two curves are nearly parallel with an average temperature difference of 12°C. The measured 16 hour equilibration curve indicates that the temperature increase cannot be due solely to additional 104 hour equilibration time. It is more likely an effect of slight increases in the rate of convective fluid flow brought on by a reduction in confining pressure induced by drilling, and a gradual breakdown of the mud cake on the sides of the hole. Water migration zones into the hole are indicated in the post-drilling profiles at 255 - 265 metres and at approximately 300 metres.

The segment of the bottom-hole temperature profile below 800 metres is crudely parallel to the calculated boiling curve. A similar relationship in several holes at Yellowstone Park is attributed (White et al, 1975) to thermal conduction outward from nearby boiling two-phase up-flow systems. Boiling has not occurred in any South Reservoir holes drilled to data, therefore, the possibility of boiling water near to M7-79D is tentative. Some change in temperature gradient is to be expected at the upper limit of hot-water migration and it may be coincidentally parallel to the boiling curve.

5.3.5 Summary of Well M8-79D (Total Depth - 290.4 metres)

Well M8-79D, located west of No Good Creek, was specifically designed, in conjunction with well M7-79D, to assess the sharp western boundary of the South Reservoir resistivity anomaly.

A graphic log of the core is presented in Figure 5.5. The hole penetrates mixed biotite hornblende quartz diorite, quartzofeldspathic gneiss, and hornblende amphibolite. Foliation angle to the core axis varies from thirty-five degrees near the top to fifty degrees in the bottom section of the hole. A light-grey, porous, dacitic, feldspar porphyry dyke, with irregularly-shaped volcanic xenoliths, is bounded by faults at 207.0 and 227.5 metres. Overlying rocks are quartzofeldspathic gneiss while footwall rocks are banded hornblende amphibolite. The mode of dyke occurrence along faults is similar to that of hypabyssal intrusions in M6-79D and M7-79D, however, distinctions in lithology suggest that the dyke in M8-79D is related to a different volcanic episode.

Faults and surface weathering result in fragmented core from bedrock surface to 45 metres depth. The amphibolite unit from 88.5 to 171.0 metres is intensely sheared and faulted and of particularly poor rock quality. Mud circulation was lost to bedrock throughout the drilling program.

Weak propylitic alteration (chlorite, epidote, calcite) is pervasive throughout the core and broken sections of amphibolite are intensely chloritized. Fault zones are characterized by clay-carbonate-chlorite ($\pm$ hematite and siderite) gouge. The feldspar porphyry is moderately altered to a clay-carbonate assemblage.

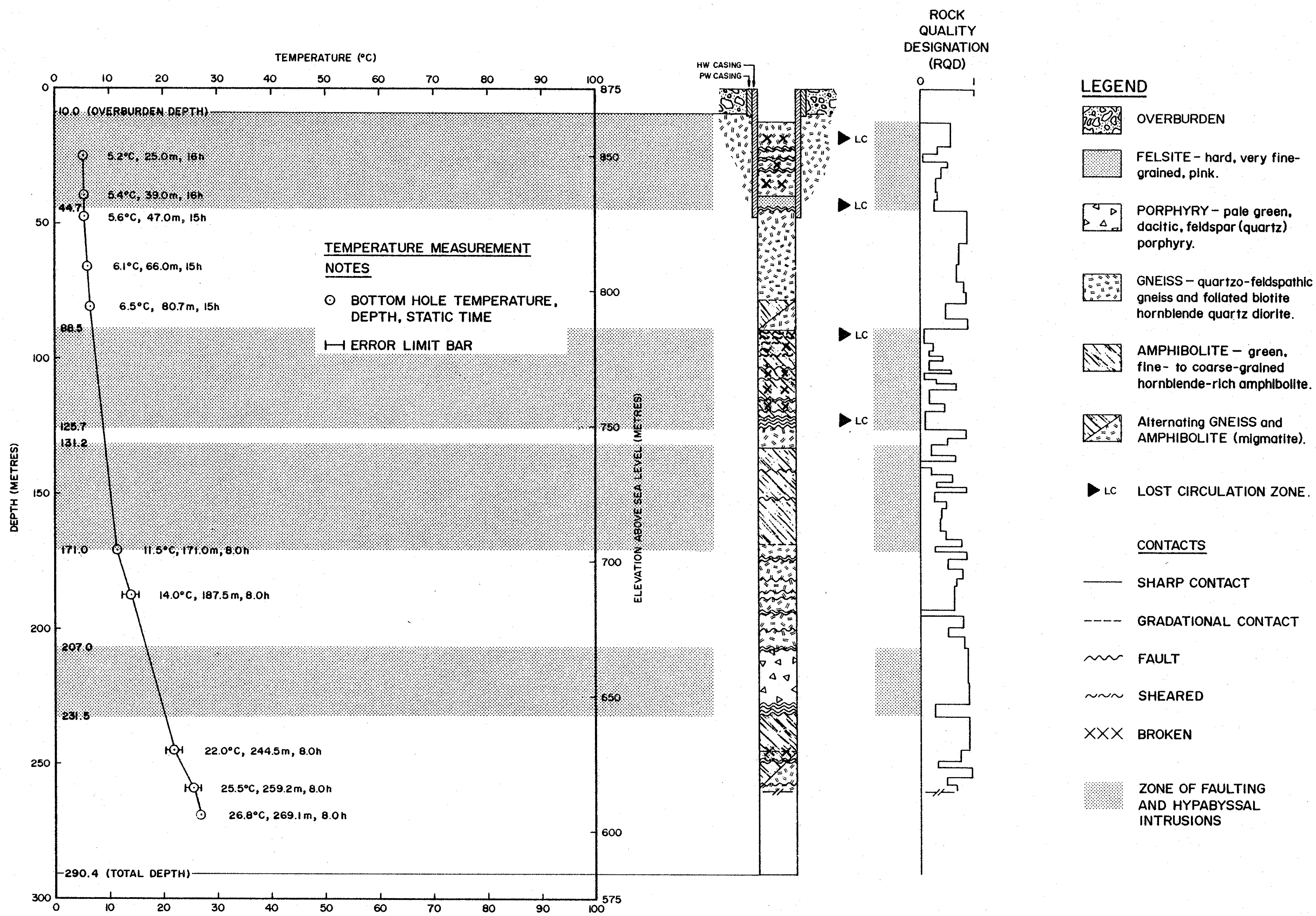


FIGURE 5.5

TEMPERATURE PROFILE AND GRAPHIC LOG RESEARCH WELL M8-79D (79-H-3)

Late carbonate veinlets are present throughout the core while carbonate scales are common on fractures below 125 metres. Minor silica precipitate occurs at depths greater than 207 metres.

The bottom-hole temperature profile is presented in Figure 5.5. Maximum temperature recorded is 26.8^{o}C. The gradient in the upper section is 23^{o}C/km, improving to 156^{o}C/km with depth. No hot or warm water flows are evident.

5.4 Bedrock Topography and Surficial Geology of the Meager Valley

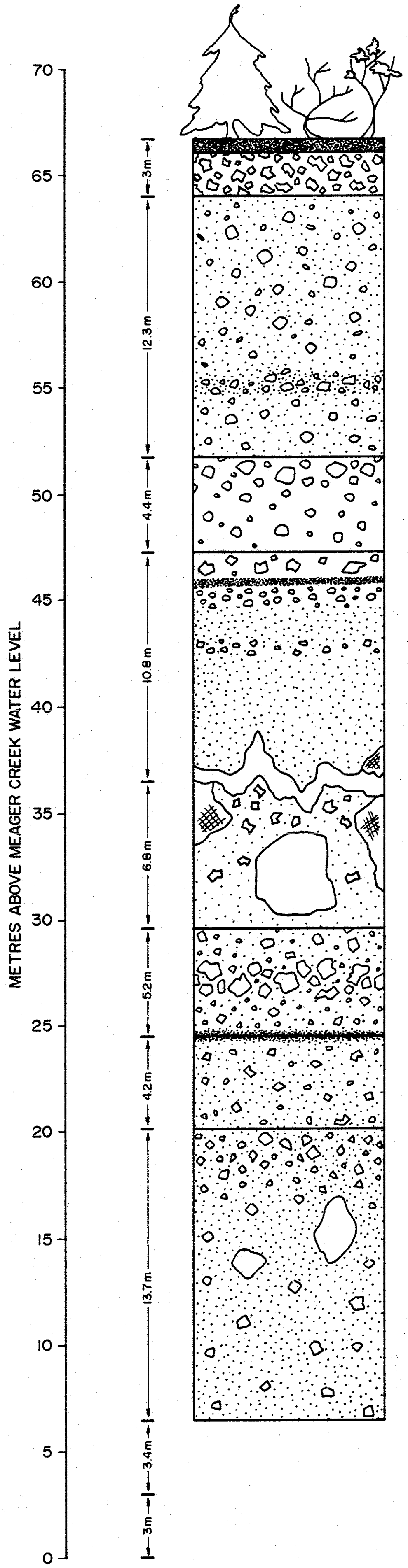
The bedrock topography and the nature of surficial deposits in the Meager Valley are of fundamental concern in understanding the system hydrology, determining the source locations of hot water in the South Reservoir, and in siting drill holes. The valley detritus is in excess of 250 metres thick (M5-78D). The original steep-walled, V-shaped valley is choked with land-slides, rockslides, lahars, mudflows, volcanic flows, and inter-calated glacial deposits (refer to Figures 5.6 and 5.9).

The rate of deposition has exceeded the rate of removal of valley fill by Meager Creek, consequently the present creek is 200 metres above its former level. Filling of the Meager Valley from the north has forced Meager Creek to flow against the south wall of the valley and, in places, to cut into the basement bed-rock. Consequently, bedrock outcrops on both banks of the creek at two locations, giving the false impression that Meager Creek is the base elevation of bedrock. Extrapolation of visible bedrock topography and drill hole data indicate a steep-walled (45^{o} slopes), V-shaped bedrock surface.

Initial development of the valley was probably caused by a combination of several processes. The south wall of the Meager Valley at the South Reservoir may coincide with a significant normal fault. Fault displacement, due to a combination of crustal extension and subsidence of the Meager Volcanic Complex, provided topographic relief for rapid erosion of the north slope and valley bottom.

Early deposits in the valley are glacial as indicated by drill data from M1-74D which encountered a clay unit of lacustrine origin upon bedrock. This clay unit, which probably lies near the center of the paleo-channel, is due either to a bedrock high near the main hotsprings vent or glacial damming by ice or moraine deposits. Evidence in support of the former is the lower elevation of bedrock at M1-74D compared to the hotsprings vent. Other clay layers and till deposits were intersected in M1-74D.

The majority of material filling the valley consists of colluvium from the Meager Volcanic Complex. Volcanic boulders in excess of 20 metres length can be found in the float of the valley. A measured vertical section near the mouth of Angel Creek (Figure 5.6) displays a sequence of mudslides and possible lahars, all of which contain angular to subangular clasts of volcanic debris. Drill evidence from several holes (M1-74D, M3-75D, M6-78D) indicates that the sequence of units as mapped in the vertical measured section extend over some area. The section appears to be devoid of glacial deposits although the thick sandy unit near the top could be a poorly developed till. More recent evidence for the mass wasting of the Meager complex is exhibited by large colluvial fans such as at No Good Creek, the Devastation slide of 1975, and the No Good Creek mudslide which occured in 1979.



Organic soil.

Angular, rubbley surface debris.

Brown, clayey sand containing angular and sub-angular pebbles and cobbles of volcanic debris. Most of the debris consists of red porphyry dacite with flow banding evident in some samples. Some poorly developed layering exists in the horizon.

Red clay unit containing clasts of red volcanic rock (5-50 cm diameter). Clasts more numerous near the top of the horizon.

White clay zone (possibly altered ash) containing angular cobbles of highly altered volcanic rock.
10 cm thick zone of fine assorted rubble (maximum diameter 1 cm).
Red clay unit with red volcanic cobbles throughout.

Fine to medium grained, white to tan coloured ash unit. A volcanic clast horizon appears near the top of the ash.

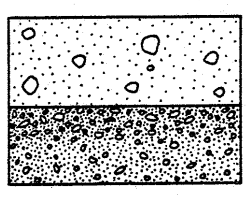
Highly irregular contact with a 0.5 m thick band of fine, white, clayey ash.

Horizon containing large blocks (3-8 m diameter) of red-pink volcanic rock entirely altered to clay. White phenocrysts altered to clay and limonitic remnant fractures exist within the altered rock. Elsewhere angular, finely fractured blocks of relatively unaltered volcanic rock exist (up to 2 m diameter). Surrounding the altered rock is a loose, pink sandy clay with pink and white sand clasts. Near the top of the horizon there are angular volcanic cobbles. The unit could be the highly altered and disturbed shoulder of a volcanic flow trending down the Meager Valley.

Lahar horizon - Black andesite clasts within a brown clayey sand matrix. The volcanic clasts are highly angular cobbles and boulders of a vesicular andesite with feldspar phenocrysts up to 5 mm diameter. Clasts are largest near the middle and bottom of the horizon and are up to 0.5 m diameter.

Rusty-yellow coloured sandy clay with fine angular volcanic clasts. Contains some rounded volcanic pebbles and cobbles. Some of the larger clasts are altered entirely to clay.

Light brown clayey sand consisting of medium to coarse grained, reddish-brown, yellow, white and black angular clasts probably of volcanic origin. The unit is scattered with angular to sub-angular cobbles and boulders of volcanic origin. Some of these clasts are altered entirely to clay. A predominance of finer clasts (½-10 mm) exists at the top of the section. Erratic large boulders of highly altered and fractured andesite (?) occur in the unit. Dry spring deposits within the unit leave a white mineral coating on the clay.



Recent mudslide debris from top of section which obscures underlying bank. Debris consists of mud with red, pink and white coarse grained volcanic sand clasts.

Assorted creek terrace and channel deposits.

— MEAGER CREEK WATER LEVEL

FIGURE 5.6

MEASURED SECTION OF SURFICIAL GEOLOGY, MEAGER CREEK NORTH BANK - SOUTH RESERVOIR

The large volume of crudely stratified debris filling the valley acts as a substantial storage aquifer for hot water emitted from the South Reservoir. Water plumes probably flow mainly within certain more porous unconsolidated horizontal units. Laterally extensive, soft buff-coloured clay alteration of certain overburden horizons derived from acidic volcanics is attributed to permeating geothermal solutions. The actual zones where hot water emanates from bedrock are masked by the overburden because saturated units containing vertical variations in permeability tend to channel water for significant distances horizontally before allowing it to reach surface.

5.5 Geochemistry

A limited amount of water sampling and chemical analytical work was conducted over the South Reservoir in 1979. Of primary interest was a zone at 60 metres depth in drill hole M6-79D which produced water at approximately 28^{o}C and at a rate of 2 litres per minute. Table 5.1 presents the reservoir temperatures predicted by the Na-K-Ca and SiO_2 geothermometers for three samples.

Temperature estimates made with the Na-K-Ca geothermometer do not indicate the existence of high temperature thermal waters. The silica chemical thermometer produces slightly higher temperature estimates than that of the Na-K-Ca method. This combination is inconsistent with previous experience at Meager Creek where the high temperatures are predicted with the Na-K-Ca thermometer. The inconsistency can be attributed to the presence of drilling mud and cement in the hole. These drilling contaminants have an unknown but probably significant effect on the reliability of the Na-K-Ca thermometer and to a lesser extent the silica thermometer. Regardless, measured temperatures in the South Reservoir exceeding 200^{o}C suggest that the sampled water has largely re-equilibrated with cooler rock and contaminants with respect to Na, K, Ca and silica. Alternately, the water produced from the 60 metre zone does not emanate from the hot reservoir.

During November, 1979, representatives from Amax Exploration, Inc. sampled water from various locations in the South Reservoir area and from the Pebble Creek Hot Springs. The highest temperature predicted was 188^{o}C from the South Reservoir using the Na-K-Ca geothermometer (Shenker, pers. comm.). Since the highest temperatures measured in M8-79D were well above 188^{o}C, the Amax results only confirm the previous suspicion that the hot springs are significantly re-equilibrated relative to the source reservoir.

A new geothermometer equation presented at the Geothermal Resources Council Conference (Fournier, 1979) involves only the Na+ and K+ ion concentrations. When applied to Meager water samples, the Na/K geothermometer yields excessively high temperatures (over 800^{o}C). The sensitivity of the Na/K equilibrium to changes in temperature and chemical environment make this method only suitable for downhole sampling or sampling of producing wells where the rise-time of fluids from the reservoir is negligible. This geothermometer is not suitable for surface sampling at Meager Creek.

TABLE 5-1 TEMPERATURES ESTIMATED BY GEOTHERMOMETER IN M6-79D

Sample	Location & Data	Na-K-Ca	SiO_2
1	M7-79D water from casing zone 60-68 m NSBG	20.4°C	76°C
2	M7-79D water from casing zone 60-68 m Waterloo	21.2°C	-
3	M7-79D water from casing after completion NSBG	29.3°C	105°C

5.6 South Reservoir Geothermal Model

Heated geothermal waters occur within basement quartz diorite and, to a lesser extent amphibolite host rocks. The central part of the accessible reservoir has temperatures in excess of 200°C at depths of approximately 250 metres. Temperatures of 300°C are inferred within 800 metres of surface on the basis of extrapolated data.

Reservoir porosity is provided by tectonic structures and is enhanced by shattering, brecciation, and faulting associated with volcanic intrusion and subsidence. RQD measurements of core show a high degree of porosity across 20-metre wide, active fault zones intruded by hypabyssal dykes. Country rock is fractured to varying degrees and core pieces are rarely over 0.5 metres. Good permeability is implied by large volumes of drill fluid lost into bedrock.

Thermal water discovered in drill holes has been under very little pressure. Over-pressured hot-water or steam may be encountered at greater depths below a confining cap of sealed fractures. Generally, self-sealing is effected by silica precipitating out of solution and constricting or plugging water-courses at the cooler margins of reservoirs. In the South Reservoir, there is a direct relationship between the volume of mineral precipitate and the occurrences of fractured water-courses, however, completely sealed silica (and carbonate) fractures do not predominate or form a cap at depths penetrated (367 metres).

The first up-welling geothermal fluid in drill holes is intersected between 670 metres (M7-79D) and 700 metres (M6-79D) above mean sea-level (AMSL). Springs along Meager Creek and the upper layer of hot water flowing in overburden (M6-79D) are also at 700 metres elevation AMSL. The upper-limit of geothermal fluid penetration so far observed, therefore, appears to be almost flat. This limit may undulate according to topography, system pressure (thermo-artesian, artesian, or steam pressure), confining pressure (hydrostatic, lithostatic), and variations in local permeability.

Figures 5.7, 5.8, and 5.9 relate inferred reservoir temperatures and geology to measured drill hole profiles and resistivity pseudosections. The change to a cooler thermal regime across the western boundary of the South Reservoir resistivity anomaly at No Good Creek supports the interpretation that the anomaly is caused principally by hot water in the shallow (250 metres) and/or intermediate (250-1000 metres) subsurface. Under this interpretation the strength of the anomaly increases directly with increasing temperature, concentration of dissolved solids, and degree of bedrock fracturing.

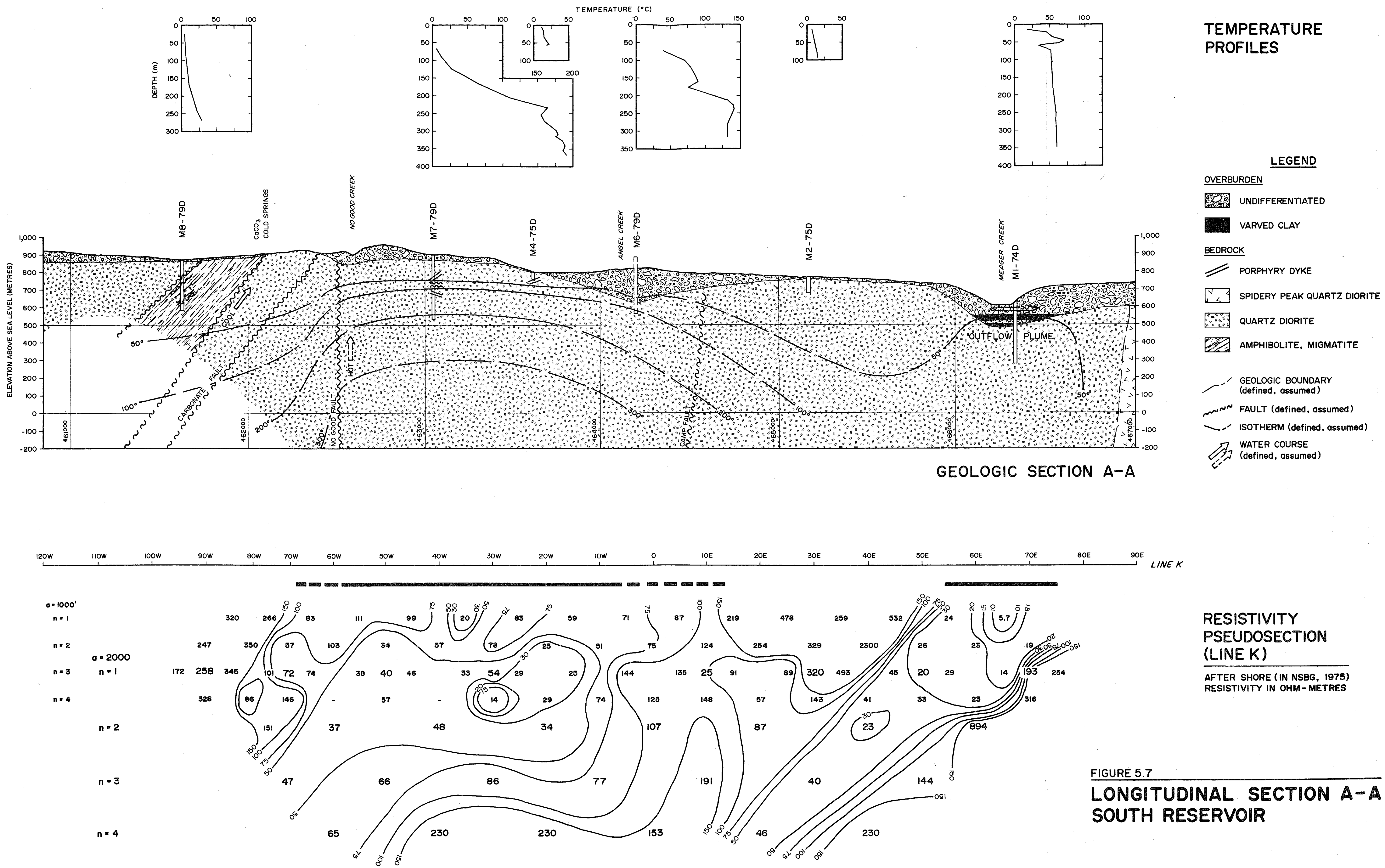
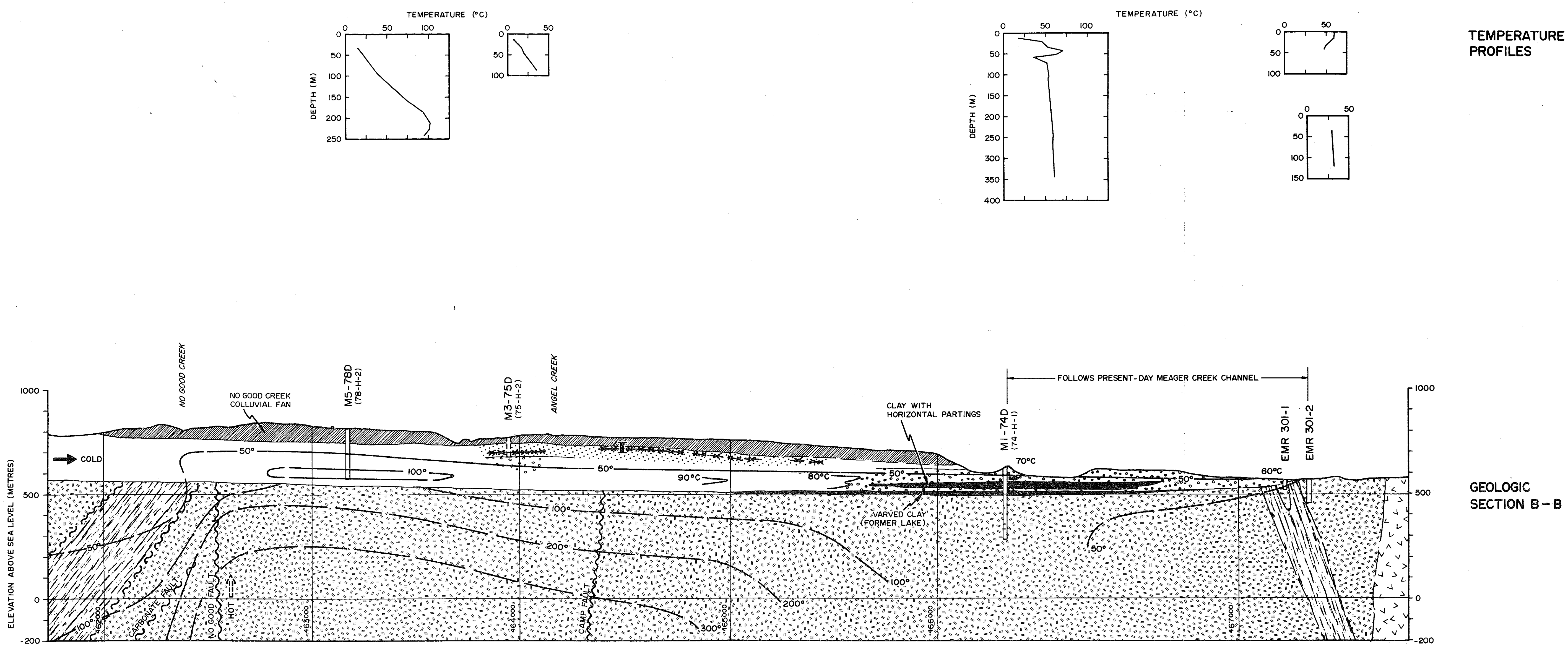


FIGURE 5.7

LONGITUDINAL SECTION A-A
SOUTH RESERVOIR



LEGEND

OVERBURDEN

- Undifferentiated
- Characterized by brown or reddish clay rich matrix containing clast and blocks of dacite and reddish andesite.
- Characterized by light brown and buff clay and sandy matrix containing volcanic clasts strongly altered to kaolinite. Includes ash and flow horizons.
- Poorly consolidated, poorly sorted glaciofluvial and fluvial sediment.
- Varved clay, compact clay, probable lacustrine deposit.
- Marker horizon of black andesite clasts in clayey sandy matrix (Lahar).

BEDROCK

- SPIDERY PEAK QUARTZ DIORITE
- QUARTZ DIORITE
- AMPHIBOLITE, MIGMATITE

- GEOLOGIC BOUNDARY (defined, assumed)
- FAULT (defined, assumed)
- ISOTHERM (defined, assumed)
- WATER COURSE (defined, assumed)
- I MEASURED SECTION OF SURFICIAL GEOLOGY (Figure 5.6).

FIGURE 5.8
LONGITUDINAL SECTION B-B SOUTH RESERVOIR

The reservoir, as presently defined by resistivity and drilling results, encloses about nine square kilometres. It terminates or deepens to the west across No Good Creek and northeastward into the mountain above drill hole M6-79D. To the north, the reservoir continues under volcanic flows toward Pylon Peak and the Devastator. The south boundary is open and unknown. The eastern margin of the reservoir ends in a narrow tail or outflow plume feeding the Meager Creek main hot springs.

Well M8-79D, west of No Good Creek, is in a much cooler subsurface environment than wells drilled into the main resistivity anomaly to the east. Either the hole is outside the lateral western boundary of the South Reservoir, or, the upper surface of hot geothermal solutions deepens westward. In the former case the Carbonate Fault or the No Good Fault might be boundaries of the geothermal cell. In the latter case the top of the reservoir might be suppressed by up-flow of relatively cool water along the Carbonate Fault System or deep circulation of cold surface water. Broken permeable amphibolite, intersected in hole M8-79D dipping at forty-five degrees, would provide a cold water channel from surface. The geologic structure in the vicinity of No Good Creek and well M8-79D is complex and a complete interpretation should be based on future mapping and drilling information.

The southern extent of the reservoir and the resistivity anomaly along Meager Creek are underexplored because of constraints imposed by rugged topography or deep overburden. High temperatures are inferred in the bedrock underlying the Meager Valley bench since a large volume of heated water (50-100^{o}C) is within the overburden itself. A single well into bedrock on the southern portion of the low resistivity zone (M3-75D) had a conductive gradient of 365^{o}C/km through 65 metres of overburden and 22 metres of bedrock.

A subsidence fault zone parallel to Meager Creek could, as a consequence of its genetic relationship to volcanism, provide a water-course inclined towards deep heat sources. A fault, based on the physiography and geomorphology of the Meager Valley, is tentatively included on cross sections for reference purposes (Figure 5.9).

In the Meager Valley, fractures display a distinct bi-modal pattern. Dominant attitudes are 153^{o}/60^{o}SW and 28^{o}/84^{o}NW. The South Reservoir may be skewed in either of the strike directions. Vertical water movement may be facilitated by preferential flow along the steeply inclining fracture planes and their mutual intersection lineament.

Untested low resistivity zones in the area of the South Fork Creek indicate a possible southern extension of the South Reservoir (Figure 2.1). Under this interpretation, the reservoir is elongated northwest-southeast, parallel to the strike of prominent fractures, major structures (eg. Carbonate Fault), and regional lineaments. The reservoir would be continuous under the eastward nose of the south wall of the Meager Valley (Figure 2.1).

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6.0 NORTH RESERVOIR

6.1 Exploration Synopsis

The North Reservoir thermal anomaly was identified in 1978 by geologic modelling, a single-line dipole-dipole resistivity survey, and a 603-metre diamond drill hole (L1-78D). Resistivity detected possible thermal waters beneath a cap of high electrical resistance. The drill hole yielded a maximum temperature of 102.8°C at 573.3 metres (the deepest measurement obtained) and a bottom-gradient of 210°C/km. A broad temperature inversion in mid-section is due to lateral convective heat flow.

6.2 Geologic Mapping

Limited geologic mapping in the Lillooet River and Job Creek Valleys augments mapping by Read (1979) of the volcanic terrane and higher elevations. Figure 6.1 shows geology superimposed on a plan map of resistivity results from a report by Premier Geophysics (Appendix E-1). Figure 6.2 shows a cross section through the target area.

The North and South Reservoirs are similar in that geothermal waters are within intrusive and metamorphic rocks, partially capped by flows of the Meager Volcanic Complex. However, important distinctions may enhance the production potential of the North Reservoir. Basement geology is much more complex. Tertiary quartz monzonite of the Fall Creek Stock is a prevalent basement rock type, extending from the Fall Creek area as far west as Job Creek. This stock is an active, multi-stage, polyphase intrusion characterized by a high degree of primary fracturing and hence a high degree of permeability. Stockwork molybdenum mineralization at Fall Creek and in drill hole L1-78D are

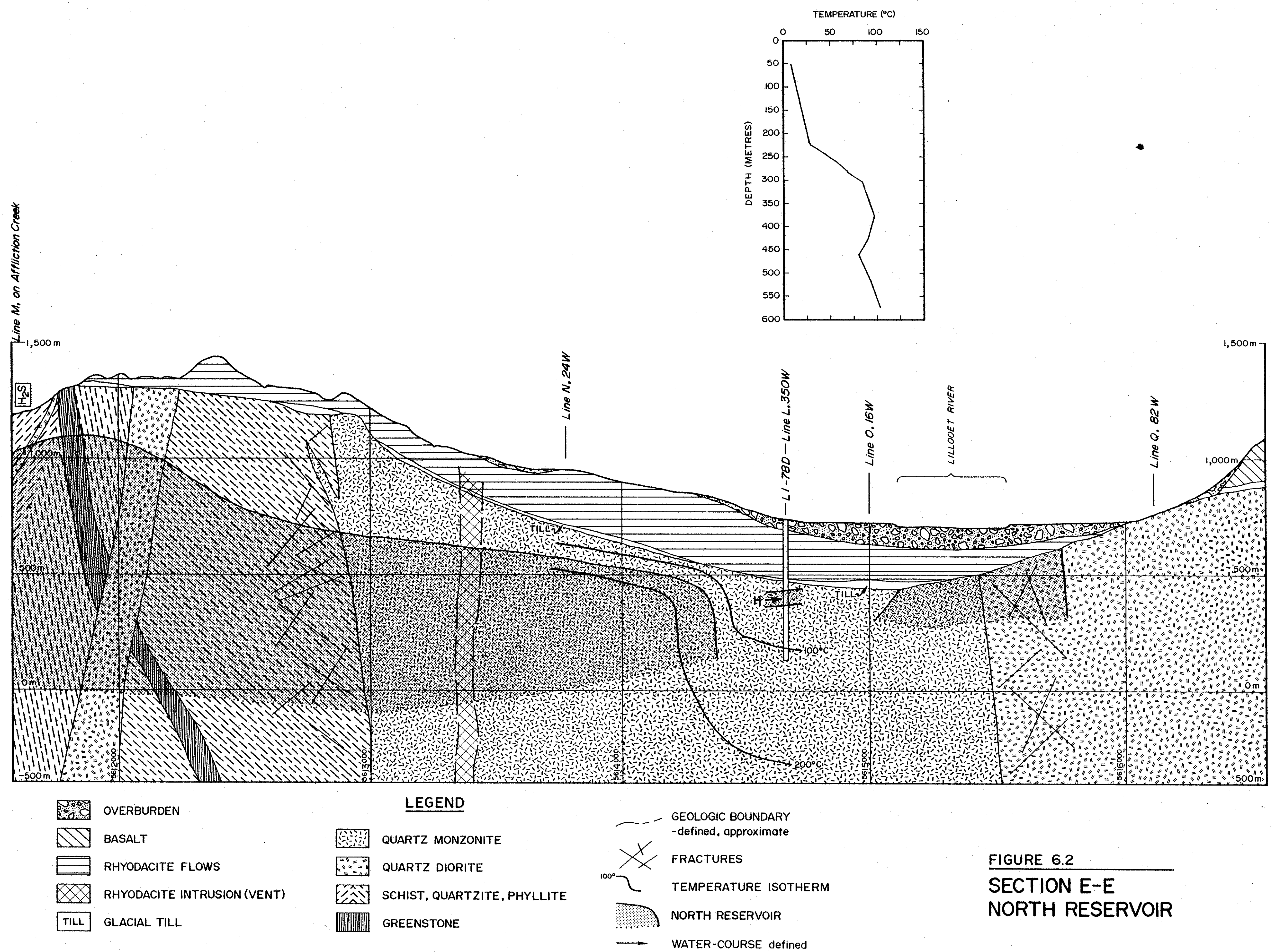

FIGURE 6.2

SECTION E-E
NORTH RESERVOIR

evidence of a long geothermal history. Relatively permeable biotite-muscovite-quartz schist, which is a continuation of the metamorphic belt on the northeast flank of Meager Mountain, outcrops extensively in the Job Creek valley. Quartz diorite, which occurs north of the Lillooet River and at the headquarters of Job and Affliction Creeks, is less extensive than in the South Reservoir area.

The Lillooet Valley metamorphic belt trends northwest and dips steeply south into Meager Mountain. At the headwaters and on the west side of Job Creek, foliation attitudes are conformable with the regional trend, however, east of Job Creek, foliation dips to the northeast. These dissimilar attitudes are interpreted as folding or faulting of the metamorphic fabric.

6.3 Resistivity Survey

6.3.1 Control Grid

In June and July of 1979 a grid was surveyed and cut in the Upper Lillooet Valley for the planned resistivity surveys and for correlation with geological and other data. It was located to bracket and extend the 1978 anomaly along Line L to test the unexplored north side of the Lillooet River. A total of 24.4 kilometres of line were surveyed by chain and compass with stations installed at 100 metre intervals. The grid consists of four lines on the south side of the Lillooet River and one line along the break-in-slope on the north side of the river (Figure 6.1).

6.3.2 Resistivity Results

A dipole-dipole resistivity survey was completed over the North Reservoir grid in July, 1979. Geophysical consultant G.A. Shore, of Premier Geophysics Inc., provided survey equipment, conducted the survey, and reduced and interpreted the data.

A detailed report of the results is presented as Appendix E-1. Nevin Sadlier-Brown Goodbrand Ltd. provided survey specifications, along with management and technical personnel.

Five anomalies were detected and are considered excellent geothermal targets (A to E, Figure 6.1). Anomaly A confirms and extends the 1978 anomaly. Although the anomaly shows good resistivity contrast and is well-defined, it remains open in every quadrant except the northwest. Anomaly B is an apparent extension of Anomaly A to the southwest into the Job Creek drainage. The remaining three anomalies (C,D, and E) are located on the opposite side of the Lillooet Valley across a broad expanse of conductive, water-saturated, glaciofluvial sediments along a single line of resistivity survey.

6.3.3 Interpretation

For background information on resistivity theory and experience generated at Meager Creek, refer to previous reports by NSBG (1974, 1975, 1978, 1979) and Deep Grid Analysis (1975).

Shore's report on current resistivity work (Appendix E-1) is a detailed account of the data including interpretation of individual anomalies. Subsequent mapping allows some refinements in the interpretation of anomalies. Along Line N, Anomaly A, defined by apparent resistivities of 200-300 metres occurring at depth, lies entirely within plutonic basement rocks which are chiefly quartz monzonite (Figure 6.1). The anomaly is in close proximity to high temperatures in drill hole L1-78D and is attributed to hot water within fractured basement rock. Where quartz monzonite is at or near surface (west of about 31W), shallow resistivity values overlying the anomaly vary from 500-1000 ohm-metres. To the east, rhyodacite porphyry flows, (thickening eastward from approximately 31W), pumice (4W - 12W), and a well-drained, sandy, detrital fan (23W - 28W) derived from the wasting of a prominent rhyodacite plug, overlie the quartz monzonite and display a high resistivity signature. The anomalous zone is continuous eastward along Line N under the high resistivity cap due to the volcanics. Anomaly A, as it appears from Line 0 to Line N, broadens southward towards Plinth Peak.

Anomaly B, although it is continuous with Anomaly A, is unique in that it is underlain largely by metamorphic schist. Along Line M, the steep intrusive/metamorphic contact is at 18N with quartz monzonite occurring to the north and schist to the south. The pattern of anomalous resistivities between 200 and 300 ohm-metres below a shallow more resistive cap is consistent with Anomaly A and is continuous across the quartz monzonite/schist contact. That is, the geological boundary is not readily discernable in the resistivity pseudosections. It is concluded from these relations that Anomaly B is caused by thermal water common to both the plutonic and metamorphic basement rather than some inherent characteristic unique to either rock type such as the presence of conductive graphite or pyrite in the schist. Anomalies A and B should be considered as separate exploration drill targets due to their different geological characteristics.

A broad expanse of glaciofluvial sediments, dammed behind volcanic flows near the Lillooet Falls, provide deep cover over the bedrock in the valley. Resistivity response from bedrock in the middle of the valley is muted, if not masked, by the sediments. Rhyodacite flows very likely cover parts of the basement in this area. On Line 0 their resistive signature is evident east of 29W. On Line P the bedrock surface is not evident due to the effect of overlying conductive sediments. For this reason any connecting features between Anomalies A and B and Anomalies C, D, or E, which lie to the north across the valley sediments, are not discernable in the resistivity data.

Anomalies C, D and E, are identified on a single line of resistivity only. Geological mapping and further resistivity work are required to allow a more definitive interpretation prior to drilling in this area.

6.3.4 Lillooet Valley Resistivity Anomaly

Limited field work was done on the Lillooet Valley Resistivity Anomaly shown on Figure 2.1 (NSBG, 1979). Field observations, along with a compilation of geology from Read (1979) and Silver Standard Mines (1973), show a remarkable correlation with the phyllite member of the metamorphic group and the anomalously low resistivities detected. This could be attributed to geothermal hot water and/or conductive minerals such as graphite or pyrite inherent to the rock. Massive greenstone overlying the phyllite on the northeast slope of Meager Mountain is not conductive nor are metamorphic rocks on the north side of the Lillooet Valley. The lower boundary of the low resistivity zone coincide with the contact between the phyllite and the Fall Creek Stock.

6.4 Preliminary North Reservoir Geothermal Model

The 1979 surveys greatly enhanced the understanding of the configuration of the North Reservoir. This section describes a preliminary working model of the system to be used to guide further exploration.

A large geothermal reservoir is indicated by resistivity anomalies A and B. The reservoir widens towards, and may be centered under, the north ridge of Plinth Peak. It is not cut off to the west and may extend to Affliction Creek. No bottom can be seen to the hydrothermal cell from the resistivity values which generally decrease with depth. The top surface of the cell is 200 metres deep at the break-in-slope along the base of the mountain (Line L) and appears, from limited data, to be almost flat into the mountain. Local upward bulges in the reservoir can be expected. Thermal water is first encountered in drill hole L1-78D at 300 metres.

Temperatures in the main reservoir zone are greater than the maximum recorded temperature of 101.8°C in drill hole L1-78D. A temperature inversion in midsection shows the hole to be on the margin of the geothermal system.

The reservoir is hosted in basement quartz monzonite and metamorphic rocks, covered in part by rhyodacite flows up to 200 metres thick. Thermal water is contained in faults and open fractures within the quartz monzonite, and in fracture melanges and intergranular pore space within the metamorphic unit. Sedimentary horizons at the base of the volcanic pile and the quartz monzonite/schist contact may be particularly good aquifers. Reservoir traps may be affected by volcanic flows, by self-sealing due to precipitation of minerals out of hydrothermal solution, and by folding or faulting of tabular aquifers.

Several lobes from the main reservoir zone under Plinth may extend outward to the northeast. The following points are left open for discussion and future resolution. Firstly, the lobe represented by the north part of Anomaly A may be continuous with Anomaly E. Secondly, the exceptional size of the North

Reservoir resistivity anomaly, and its southward extent up Job Creek, lead to speculation that it is continuous with the Lillooet Valley Resistivity Anomaly (Figure 2.1). The spatial relation of the Lillooet Valley anomaly and Anomaly B with metamorphic rocks of the same belt lends credence to their geothermal association. Thirdly, the Pebble Creek hot springs below the Lillooet Falls have an abnormally high molybdenum content (Amax, 1979), probably derived from molybdenite occurring in Tertiary quartz monzonite of the Fall Creek Stock. This suggests easterly migration of geothermal fluids from the North Reservoir area. Finally, local resistivity anomalies from dipole-dipole work in 1974 (McPhar, 1974) may be present-day hydrothermal effects in the bedrock out-flow zone.

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APPENDIX B - DRILLING

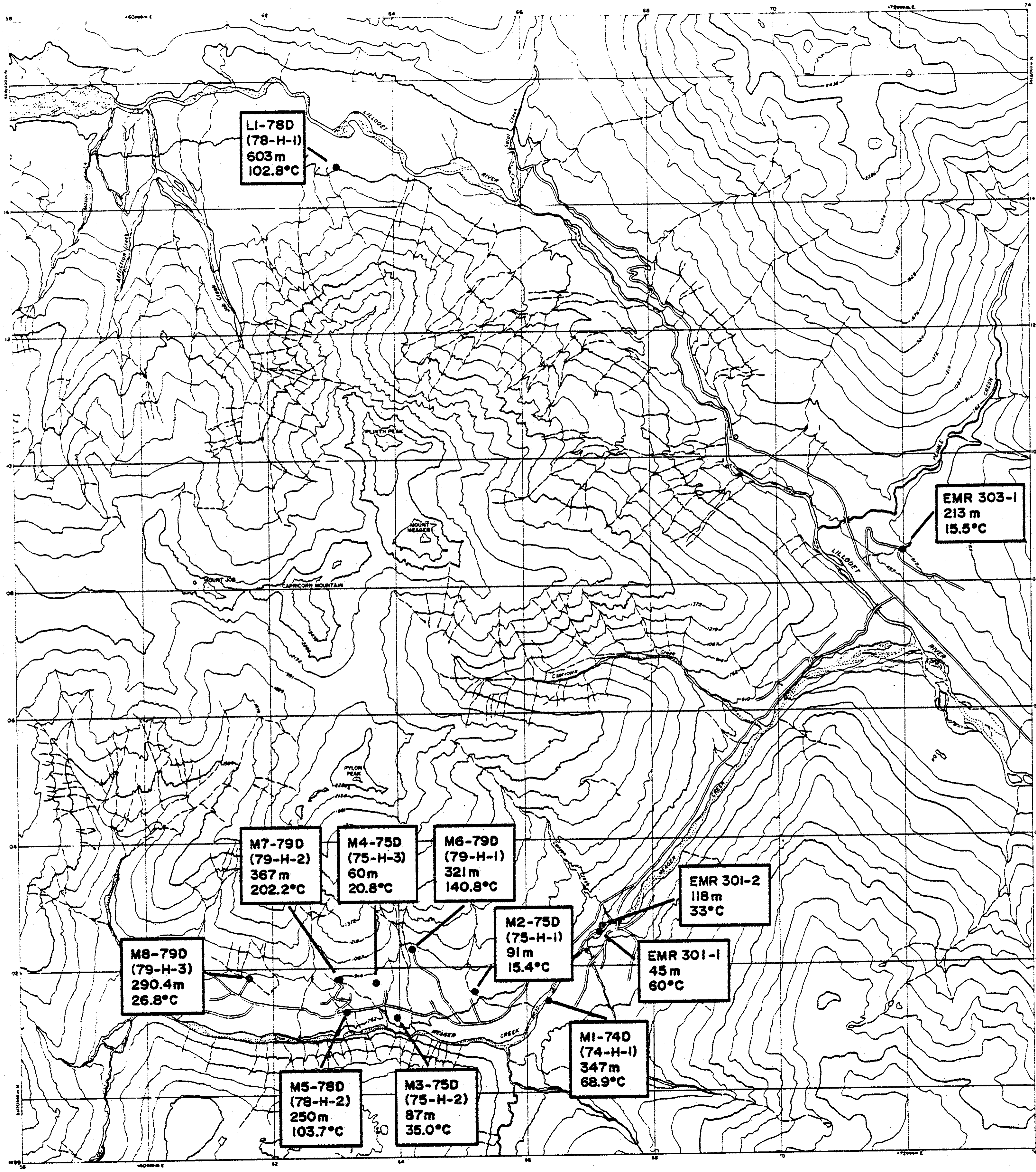
Appendix B-1: Revised Designation of Drill Holes

The number of holes now drilled in the Meager area requires the reorganization of the previous designation system where holes were named consecutively during the year they were drilled (ie. 79-H-1, 79-H-2, 79-H-3). The system now adopted employs consecutive numbering from the first diamond drill hole collared. In addition, the South Reservoir and North Reservoir are being treated as separate drilling projects. To distinguish the South and North Reservoirs the letters M (for Meager drainage) and L (for Lillooet drainage) precede the number of the hole. To complete the naming of the hole, the year of drilling (ie. 75, 78, 79, etc) and a letter signifying diamond (D), percussion (P), or rotary (R) drilling are included. The old designations, along with the appropriate new designations, are shown in Table B-1. It is anticipated that as the number of drill holes continue to increase, the new system will be a significant improvement over the previous naming system.

Table Showing Revised Designations of Drill Holes

Old	New
DDH 74-H-1	M1-74D
DDH 75-H-1	M2-75D
DDH 75-H-2	M3-75D
DDH 75-H-3	M4-75D
DDH 78-H-1	L1-78D
DDH 78-H-2	M5-78D
DDH 79-H-1	M6-79D
DDH 79-H-2	M7-79D
DDH 79-H-3	M8-79D
(DDH 80-H-1)	(M9-80D)

Key:
M = Meager Drainage
L = Lillooet Drainage
D = Diamond Drill Hole
P = Percussion Drill Hole
R = Rotary Drill Hole



LEGEND

● LOCATION OF HOLE

M3-75D	NEW DESIGNATION OF HOLE. (EMR indicates Energy, Mines and Resources, Canada)
(75-H-2)	PREVIOUS DESIGNATION OF HOLE.
87 m	DEPTH IN METRES.
35.0°C	MAXIMUM HOLE TEMPERATURE

NOTE: Designations for holes drilled by Energy, Mines and

APPENDIX B-2

SUMMARY MAP OF DIAMOND DRILLING SHOWING REVISED HOLE DESIGNATIONS

APPENDIX B-3: SUMMARY OF DIAMOND DRILLING

NEW HOLE DESIGNATION	OLD HOLE DESIGNATION	LOCATION	COORDINATES	DATE COLLARED (DRILLED BY)	COLLAR ELEVATION(m)	DEPTH(m)	DEPTH OF OVERBURDEN(m)	MAXIMUM TEMPERATURE(°C)	BHT GRADIENT AT BOTTOM (°C/km)	COMMENTS
n.a.	301-1	Meager Creek hot springs	5,602,540N 467,160E	March 74 (EMR)	587	45	18	60	n.a.	- hole inclined at -70° - making water at 6 l/s - temperature inversion, -ve gradient at bottom
n.a.	301-2	Meager Creek hot springs	5,602,640N 467,200E	March 74 (EMR)	583	118	0	33	44	- making water at 1.7 l/s
n.a.	303-1	Lillooet Valley	5,608,510N 471,970E	Sept 77 (EMR)	580	213	0	15.5	48	- making water at less than 1 l/s
M1-74D	74-H-1	South Reservoir Outflow Plume	5,601,440N 466,350E	Nov 74 (B.C. Hydro)	635	347	124	68.9	27.7	- making water at 3 l/s - temperature inversion in overburden section
M2-75D	75-H-1	South Reservoir	5,601,610N 465,200E	Sept 75 (B.C. Hydro)	774	91	11	15.4	112	- making water at 0.3 l/s
M3-75D	75-H-2	South Reservoir	5,601,200N 464,015E	Sept 75 (B.C. Hydro)	770	87	65	35.0	365	
M4-75D	75-H-3	South Reservoir	5,601,770N 463,000E	Sept 75 (B.C. Hydro)	808	60	12	20.8	289	- inclined at -70°
L1-78D	78-H-1	North Lillooet Valley	5,614,630N 463,090E	Sept 78 (Joint Venture)	760	603	47	102.8	211	- temperature inversion between 387 and 450m
M5-78D	78-H-2	South Reservoir	5,601,310N 463,160E	Oct 78 (Joint Venture)	822	250	250	103.7	n.a.	- temperature inversion in bottom section
M6-79D	79-H-1	South Reservoir	5,602,280N 464,280E	July 79 (B.C. Hydro)	885	321	15.6	140.8	n.a.	- temperature inversion in mid section - near isothermal in bottom section
M7-79D	79-H-2	South Reservoir	5,601,850N 463,060E	Oct 79 (B.C.Hydro)	900	367	26	202.2	225	- gradient inflection near 300m.
M8-79D	79-H-3	South Reservoir	5,601,870N 461,630E	Nov 79 (B.C. Hydro)	875	290.4	10	26.8	156	- extension planned for 1980

APPENDIX B-4

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET.

Hole No. M6 - 79D (79H1)

Sheet 1 of 11

Project Location Meager Creek-South Reservoir Co-ordinates 5,602,280N; 464,280E Collar elevation 885 m (2900 ft.)

Date Started July 18, 1979 Date Completed October 7, 1979 Total Depth 321 m Type/Size of Bits HQ, BQ

Drilling Contractor BC Hydro - Construction Dept. Drilling Section Geologic Log By BDF Geophysical Log By BDF/JR

General Summary Comments

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl.Ep.Cal / SiO2 Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
0	21.4	21.4		triconed (to 7 7/8")		Overburden 0-9.4 Blocky talus 9.4-15.2 Alternating clay-rich reddish soil and greyish soil with blocky rocks. 15.2-15.6 Tight, well-packed					
21.4	37.3	15.9		triconed		rocky horizon. 15.6-21.4 Dark brown mud return Blocky rocks 21.4-37.3 AMPHIBOLITE. green and white sandy sludge.					
37.3	40.0	2.7	97	cored with H later triconed to 7 7/8"		37.3-49.0 green-grey AMPHIBOLITE mainly hornblende, feldspar, quartz, epidote; fine to medium-grained with indistinct foliation; composition layering at 40-45° to C.A.	minor fine botryoidal SiO_2 on fracture oxidation on fractures to 50 m.				37.3 0.48
40.0	45.0	5	95		WEAK TO MODERATE		weathered, broken rx.				40.1 0.05 43.3 0.47

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

Sheet 2 of 11

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl.Ep.Cal / SiO2 Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
45	50	5	97	6" T&C pipe for casing set at 45.6m 7 7/8" hole to 53 m.	WEAK / WEAK	47.0 minor gouge 49.0-49.5 med. grey fine-grained DACITE, minor small white amygdules.	48.3-50.0 fault gouge almost completely clayand hematite.				0.47 46.8 0.17 48.9
50	55	5	70	Rock broken and crumbly to 49 m.	STRONG / MOD	49.5-50.0 clay-hematite gouge. Original rock destroyed. 50.0-51.0 RHYOLITE FAULT BRECCIA 51.0-52.5 aphanitic fine-grained cream-coloured RHYOLITE	50.0-62.2 strong kaolinization with gouge zones completely altered to clay, hematite minor carbonate. More				0.68 51.5 0.11
55	60	5	95		WEAK	52.5-55.5 MYLONITE; dark grey-green, intensely sheared 45° to C.A. probably derived from amphibolite. 55.5-58.6 light grey to creamy white RHYOLITE; aphanitic, brittle fracture.	competant rhyolite sections are less affected.				56.0 0.42 58.5 0.13
60	65	5	90	60m coretube came back hot. Water flow into hole at 60m, cased of	STRONG / MOD	58.6-62.1 FAULT GOUGE; some sections completely altered to clay, original textures destroyed. Light grey colour	62.2-68.6 kaolinite-calcite along fractures (greater than 5/m)				60.5 0.73 62.2 0.75 63.7
65	70	5	90	with HW casing to 68.6m. Volcanic dyke hard, brittle	TO WEAK	with graphite. 62.1-68.6 light grey to creamy white RHYOLITE; faint flow banding at appr. 20° to C.A. ▲66.5 Rock sample 79H1-66.5					0.23 66.2 0.57 68.6 0.97
70	75	5	97	well-fractured. Relatively competent Good recovery		flow banding in RHYOLITE more pronounced within 20cm of contact. Banding and contact 45° to C.A. 68.6-88.5 Dark grey-green GNEISS; medium-grained granoblastic texture; biotite and horn-blende variably altered to chlorite (50%), feldspar(30%), quartz (15%), accessory (5%), including disseminated pyrite (1%) ▲74.0 Rock sample 79H1-74.0	68.6-78.8 Rare quartz-carbonate encrustations on fractures. Minor calcite and quartz veinlets (1/m) Epidote flooding forms envelopes around tight fractures. 73.6 10cm hematitic gouge.	72.5	41.4	BHT. 4 hr. static time good rebound curve-temperature near equilibrium.	70.8 0.23 71.7 0.84

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

Sheet 3 of 11

Depth (m) From	To	m.	% rec.	General hole conditions	Graphic log (Chl.Ep.Cal / SiO2,Ser / Kaolinite / Rock)	Rock type, description, structure, fracture density	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation	RQD
75	80	5	97	Relatively competent fresh, good recovery		78.8-85.1 includes fine-grained more siliceous sections.	78.0 reddish hematitic slickensides 78.8-85.1 increased fracture density and epidote content.				0.84 / 79.8
80	85	5	97				(gradational change from above) 80.3 drusy quartz vein (open space filling)				0.65 / 82.3 / 0.42 / 83.2
85	90	5	95	soft zones	MOD	88.5-93.5 light emerald green, aphanitic DACITE containing small white blobs	85.1-88.5 shear zone cleavage at 47° to C.A.; reddish hematite ass.w. shearing. Hematite-quartz ppt. in fractures.				0.72 / 85.1 / 0.00 / 86.2 / 0.58 / 88.8
90	95	5	97	mainly competent	ST	of quartz-carbonate replacing inclusions and/or feldspars. ▲90.0 Rock sample 79H1-70.0 93.5-93.8 hematitic gouge. 93.8-99.5 altered AMPHIBOLITE;	88.5-93.5 calcite-quartz veins and replacement blobs within dacite. 93.5-93.8 hematite-kaolinite gouge.				0.92 / 92.6 / 0.46 / 94.8
95	100	5	95	rock competent good recovery	MOD / MOD	green color imparted by pervasive chlorite-epidote alt'n of mafics in layers and streaks. Feldspars partly kaolinized Quartz & feldspar grains ragged (≈50%)	93.8-99.5 mafics altered to chlorite, epidote (± silica) flooding, feldspars weak to moderately kaolinized. Quartz veins and quartz-				0.89 / 99.5
100	105	5	97		WEAK / WEAK	99.5-101.0 pale green, dacitic crowded FELDSPAR PORPHYRY 101.1-101.4 contact BRECCIA; amphibolite in dacitic matrix (Fragments to 4cm) 101.4-113.0 granoblastic AMPHIBOLITE grading to GNEISS and foliated QUARTZ DIORITE	carbonate ppt on fractures (1-2/m) 99.5-101.0 groundmass saussaritized 101.0-139.0 minor quartz carbonate (carb>qtz) flakey precipitate on fractures ± hematite and epidote (fractures 1-2/m)	104	64.6	7.5 hr. static time	0.40 / 101.1 / 0.93

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

Sheet 4 of 11

Depth (m) From	To	m.	% rec.	General hole conditions	Graphic log (Chl.Ep.Cal / SiO2,Ser / Kaolinite / Rock)	Rock type, description, structure, fracture density	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation	RQD
105	110	5	97	rock hard competent.		contains short fine-grained mafic-rich intervals and local streaks of light green epidote. Gneissocity 65° to C.A.	as before (minor quartz veins, quartz-carbonate ppt. on fractures (1-2/m)				0.93 / 109.4
110	115	5	97		VERY WEAK / VERY WEAK	110.0 minor fault gouge 40° to C.A. 111.1 offset across qtz. vein 20° to C.A. Gradual change to					0.56 / 111.5 / 0.95 / 112.8
115	120	5	97			113-167.5 fine and medium-grained, foliated, coarsely-banded AMPHIBOLITE and GNEISS; texture and composition variable. Bulk composition approximately					0.71 / 116.8 / 0.72
120	125	5	97		WEAK	hornblende 35-40%, plag 30-35%, quartz 20-25%, chlorite-epidote 10%, pyrite 1-3%, accessories 1-5% Contains fine-grained hornfels sections of quartz diorite bulk composition.		123.5	79.0	7.5 hr. static time	120.5
125	130	5	97	Rock very competent.		Relatively uniform and mundane.					0.91
130	135	5	97		WEAK						130.6 / 0.77

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
135	140	5	97	hard rock						gradational to:				0.77 137 0.80
140	145	5	97			WEAK				140-160 silica,silica-carbonate-epidote-chlorite and kaolinite precipitates on fractures (density 3/m)	143	87.7	measured temperature after 9 hr. static time (not equilibrated)	143.6 0.96
145	150	5	97		WEAK					▲146 U of Waterloo calcite ppt sample.		93.0	estimated equilibrium temperature from graph	145.5 0.71
150	155	5	97	Advanced HW casing to 62.9 m. Making									Sample of water coming out between P and HW casings from about 60m.	150.5 0.80 152.9 0.41 154.5
155	160	5	97	warm water between P and HW casings from 60m.	WEAK	WEAK TO MOD		BX	157.4 Drusy qtz vein o.5cm 157.4-157.9 Breccia healed with K-spar-quartz-epidote. Envelope for 3m each side of marble textured sections	gradational to:				0.91 157.6 0.60
160	165	5	97	hard rock		WEAK			with increased epidote and quartz.	160-177.5 White carbonate precipitate on chloritic fracture and slip surfaces. 162.1 Felsite vein with disseminated pyrite, diffuse contacts.	162.5	90.5	8 hr. static time	160.8 0.87 164.0 0.74

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
165	170	5	97	167-179 softer ground		VERY WEAK			167.5-177.5 streaky AMPHIBOLITE; streaky compositional banding at approx 45° to C.A.; alter-	165.5 quartz vein with pyrite and magnetite; 0.3 mm wide. 166.6 quartz vein with pyrite and magnetite,				0.74 167.0 0.91
170	175	5	90				ST W		nating dark green and light grey bands. Increased mafics (50-55%) from previous interval. 171.8-172.3 gouge and minor fault breccia in fault zone.	10cm width with diffuse contacts. 171.8-172 strong kaolinization with graphite in fault zone.				170.5 0.23 174.5
175	180	5	95	178 lost return (restored with mud plug)					Attitude? gradational bleached contact 177.5-186.5 RHYODACITE PORPHYRY; White feldspar phenocrysts to 3mm in light to med-	173-174.5 weak to mod chlorite,sericite in broken zone. 177.5-186.5 Carbonate precipitate on fractures;	179	76.8 80.8	8 hr. static time,6 hr downhole with high temp. element, 8½ hr. static time,½h downhole with	0.96 176.8 0.22 179.0
180	185	5	95	soft rock			WEAK TO MOD.		ium-grey aphanitic groundmass ▲184.6 Rock sample 79H1-184.6 186.5-187.8 aphanitic,buff cloured RHYOLITE; kaolinite gouge zone at both ends of	well developed calcite crystals lining surfaces of open fractures;weak kaolinization pervasive, feldspar phenocrysts			low temp element (Water disturbed by previous measurement).	0.51 181.9 0.31 185.0
185	190	5	85	189.2-190.5 partial return loss.	WK			BX	section.Open spaces in brittle fractures with kaolinite. 187.8-190.5 healed BRECCIA; fine-grained angular light green fragments with sub-	saussaritized. ▲180-180.5 U of Waterloo calcite ppt. samples 186.5-187.8 Carbonate and kaolinite powder				0.48 186.6 0.16 188.0 0.57
190	195	5	97	191-204.5 lost mud 3-4 times but getting some return	MOD		MOD		parallel network (45° to C.A.) of carbonate-hematite cemented fractures. ▲187.0 Rock sample 79H1-187.0 190.5-191.5 altered AMPHIBOLITE transition zone. Contact attitudes uncertain.	(white) in open fractures. 187.8-190.5 Carbonate-hematite cement;siliceous infillings ▲190.5 U of W calcite ppt sample 190.5-191.5 moderate kaolinization				191.5 0.83

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
195	200	5	97	getting into more solid ground					191.5-230 streaky AMPHIBOLITE; dark sea-green, fine-grained mafic rich bends (hornblende and chlorite) alternating with subordinate plagioclase-	191.5-225 Buff coloured carbonate powder and scales on fractures (3-4/m); Rare calcite crystalline infillings;				0.83 197.2
200	205	5	97		WEAK TO MODERATE				rich bands and wisps. Relatively competent and hard.	hematite on some fractures	204.5	117.1	7.5 hr. static time	0.92
205	210	5	97						includes sections of 208.0-211.8 fine-grained siliceous, medium grey-green HORNFELS ▲208.5 Rock sample 79H1-208.5	208.0-211.8 thin potassic alteration envelopes (fine-grained orthoclase) along tight microfract-				208.3 0.62
210	215	5	97	BOP installed	WEAK					ures.				212.2 0.94
215	220	5	97		WEAK					×220 first near vertical	215.0	132.1	7.5 hr. static time	215.0 0.93
220	225	5	97						220-223.8 fine-grained siliceous, medium grey HORNFELS.	major fracture set encountered. 223.8 minor fault; epidote, pyrite (attitude?)				0.59 222.1 0.47 224.0 0.62

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
225	230	5	97						gradational change to:	gradational to: 225-247 carbonate scale and precipitate on fractures (2-3/m)				0.62 230.0
230	235	5	97						230-245.7 streaky AMPHIBOLITE as above but with increased light siliceous granoblastic banding and decrease in mafic horizons; alternating dark grey	231.0 3cm quartz vein 45° to C.A.	231.5	139.2 140.8	10½ hr. static time 34 hr. static time Several (three) off bottom temperature profiles run (0-231.6, 0-91.4, 152.4-	0.70 233.7 0.76
235	240	5	97		WEAK				and light grey streaks or bands. Contains sections grading to quartz diorite gneiss. ▲235.5 Rock sample 79H1-235.5		239.0	140.3	231.5) with hole at 231.5-see temperature tables. 15 hr. static time	235.3 0.91
240	245	5	97						245.7-246.0 GRANITIC DYKE; texture aplitic to pegmatitic; pink orthoclase dominant; 10cm contact alteration envelope					243.4
245	250	5	90	247.0-253 total loss of circulation "like drilling into a hole"	W				70° to C.A. (cuts foliation) 246.0-247.0 streaky AMPHIBOLITE 247.0-252.0 broken AMPHIBOLITE core extremely broken up, chlorite alt'n pervasive but	247-257 carbonate, silica, and fine greenish powder on fractures.				0.87 247.2 0.20
				249.2 try diesel plug (unsuccessful)					fragments hacky-no gouge. broken AMPHIBOLITE					

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

Sheet 9 of 11

DRILLING LOG Depth (m) From	To	m.	% rec.	general hole conditions	GRAPHIC LOG (Chl.Ep.Cal / SiO2,Ser / Kaolinite / Rock)	GEOLOGICAL LOG Rock type, description, structure, fracture density.	Alteration, veins, precipitates	GEOPHYSICAL LOG Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
250	255	5	90	no return since 247m. 252 Cement plug attempt unsuccessful	WEAK, WEAK	252.8 streaky AMPHIBOLITE; -dark grey -wavy banding distinct -competent	silica, carbonate, and fine powder-green mineral precipitated on fractures.				0.20 252.9 0.88
255	260	5	95	(no cement on bottom) no return	M, MOD	257.4-261.0 GRANITIC DYKE; -grain size and texture variable between aplitic and pegmatic -sharp angle to C.A.	257.4 quartz-sericite lesson carbonate veins to 2mm, also precipitated on fractures.				257.0 0.55
260	265	5	75	261.6 Cement plug attempt unsuccessful Cement set inside rods.	ST, M, M, ST	258.5 Rock sample 79H1-258.5 261.0-261.6 AMPHIBOLITE; dark green 261.6-263.8 soft fine-grained DACITE; dark grey to light	261.0-261.6 strong chloritization 261.6-263.8 "waxy" calcite plates on fractures	261.6	124.7	BHT 3½ hr. static time Hole temp not equilibrated Flatness of graph indicates water flowing in hole	261.4 0.17 263.0 0.13
265	270	5	75	266.0 Cement plug attempt unsuccessful 50m rods cemented in hole from	S	green(bleached) ▲263.2 Rock sample 79H1-263.2 263.8-264.4 gouge and quartz vein material (milky quartz) 264.4-265.5 sheared, dark green AMPHIBOLITE; shearing at	264.4-274.5 mainly carbonate on fracture surfaces; some quartz veins and "sweats" with diffuse boundaries. ▲271.5 U of Waterloo	266.0	125.4	BHT 4½ hr. static Hole temp not equilibrated Equilibrium temperature questimate 137.5°C	266.0 0.00
270	275	5	90	200.5-255.5 Reduce to B rods at 266 after attempt to ream H	WEAK	shallow angle to core axis (0-20°) 265.5-274.5 dark green AMPHIBOLITE; foliation and banding indistinct, broken core	calcite ppt. analysis 274.5-292 minor white carbonate encrustations and powder on some				271.7
275	280	5	95	casing over stuck H rods unsuccessful. rock hard. competent.	WEAK	274.5-284 dark green-grey streaky AMPHIBOLITE; fine color banding (dark-light) consistent at about 45° to core axis. Rock is hard, with siliceous sections.	fractures. Rock generally hard, with brittle fractures(5/m)				0.76

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. 79H1 (M6-79D)

Sheet 10 of 11

DRILLING LOG Depth (m) From	To	m.	% rec.	general hole conditions	GRAPHIC LOG (Chl.Ep.Cal / SiO2,Ser / Kaolinite / Rock)	GEOLOGICAL LOG Rock type, description, structure, fracture density.	Alteration, veins, precipitates	GEOPHYSICAL LOG Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
280	285	5	90	284 B rods broken 18m above core	WEAK, WEAK	▲281.0 Rock sample 79H1-281.0 284-292 dark grey-green fine-grained siliceous AHMPHIBOLITE and sections of HORNFELS.	-minor white carbonate encrustations and scales eg 294;101	282	132.3	8 hr. static time. Good rebound curve.	0.76 281.6 0.41
285	290	5	85	barrel. Rods fished and hole cemented in attempt to plug H sec-	WEAK TO MOD	-gradational change from previous section. 290.5-290.9 light grey fine-grained siliceous leucocratic	-minor competent milky white quartz veins (old) eg.10cm-299.4 3cm-293.5				285.0 0.29
290	295	5	90	tion below. lost H core barrel. Cement successful but new		granodiorite 292-300 dark grey-green banded AMPHIBOLITE; banding with variable thickness and orientation cut by diffuse epidote and	292-300 only minor fracturing with flaky carbonate precipitate.				292.0
295	300	5	85	B hole follows old hole; still have possible crook at 266m	WEAK	siliceous veins. -gradational change from previous section.					0.74
300	305	5	90	292. B rods broke off at 264m. Rock hard and blocky		300-311.5 light to medium-grey HORNFELS grading to fine-grained GRANODIORITE over short sections; Indistinct and irregular banding. Minor amphibolite as above.	300-311.5 fractures 4.5/m carbonate ppt. Rock is hard. ▲300.7 sample by U of Waterloo for calcite ppt. analysis				300.7 0.32 303.3 0.62
305	310	5	95	Rock hard competent slow drilling	WEAK						307.9 0.80

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Qz	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
310	315	5	97	Rock hard. competent slow drilling	WEAK		MOD		311.5-316.0 dark green-grey fine to medium-grained granoblastic GNEISS. Banding and layering indistinct.	311.5 Kaolinite fault gouge over 10cm with bleached alt'n envelope 1m each side.				0.80
315	320	5	95	Rods broken at 264m.	WEAK	WEAK			316.0-318.0 banded light to medium grey HORNFELS. Granodiorite composition. Wavy banded to marble texture. 318.0-321.0 green-grey AMPHI-	312.5-321.0 carbonate on fracture surfaces 1-5/m 318.8 13cm wide pegmatite vein 45° to C.A.	318.0	131.0	8 hr. static time-good rebound curve.	316.0 — 0.76 317.8 —
320	321	1	95	core tube lost down hole					BOLITE and HORNFELS as above.				Post drilling temp. traverse run between 205 and 321 metres where probe wedged(?) inside B rods.	0.43 321.0
									END OF HOLE					

COMPLETION NOTES: Broken B rods fished out. All rods and casing pulled except 6" casing cemented to 45.6m and lost H rod section plus core barrel between 200.5-255.5 m Attempt to line hole with 2 in. T+C black standard pipe to 249m was unsuccessful because cement set up after 45 bags Portland 10 cement pumped. Lining abandoned in hole.

APPENDIX B-5

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET.

Hole No. M7-79D (79H2)

Sheet 1 of 12

Project Location Meager Creek-South Reservoir Co-ordinates 5601 850N; 463060E Collar elevation 900 m. (2950 ft.)

Date Started October 17,1979 Date Completed November 30,1979 Total Depth 367 m Type/Size of Bits HQ

Drilling Contractor BC Hydro-Construction Department Drilling Section Geologic Log By BDF Geophysical Log By BDF, JFR

General Summary Comments

Depth (m) From	To	m.	% rec.	general hole conditions	Graphic Log (Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock)	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
0	26	26	-	triconed false bedrock at 7m.		overburden: Rocky soil several very large boulders.					
26	34	8	-	triconed		26-34 Intrusive Rock.					
34	40	6	75	Rock broken and hard to 44m. 36 m lost return hole caves	MOD	34-39.0 partially silicified, fine-grained QUARTZ DIORITE; broken, fractured and foliated gradational to - 39.0-43.5 medium-grained BIOTITE	34-43.5 Surface weathering evident along fractures-hematite and iron oxide. Weak but pervasive propylitic alteration				34.0 0.46 37.4 0.50
40	45	5	80	easily	WEAK S	HORNBLENDE QUARTZ DIORITE. plag 45%, granular quartz 20%, clotted mafical hornblende 20%, biotite 10%, chlorite 4%, epidote pyrite (tr); Foliated 35° to C.A. Broken and fractured.	(chlorite ± minor epidote) of mafic minerals; Minor fractures healed with fine-grained, epidote envelopes-diffuse 43.5-53.0 pervasive				41.2 0.19 43.6
45	50	5	95	Rock more competent		43.5-53.0 foliated BIOTITE HORNBLENDE QUARTZ DIORITE as above with marked increase in competency. (average core length 20 cm)	weak propylitic alteration (chlorite, epidote, calcite) Minor carbonate veinlets (2/m).				0.69 48.8

48.2 minor fault Attitude?

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)

Sheet 2 of 12

Depth (m) From	To	m.	% rec.	general hole conditions	Graphic Log (Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock)	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
50	55	5	95	6" welded joint pipe cemented in to 53m after reaming 7 7/8"		53.0-65.0 medium to coarse-grained equigranular HORNBLENDE QUARTZ DIORITE; relatively fresh (minor chloritization), unfoliated,	53.0-65.0 minor weathering products (iron oxide) on some fractures. Minor chloritization of mafics.				0.90 52.5 0.77
55	60	5	60	to 56 m. core missing 56-57.2 (triconed) When drilling		euhedral plag 55% anhedral quartz 15-20%, euhedral hornblende 20%, biotite 3%, chlorite replacing hornblende 5%, accessories pyrite-trace.					56.0 triconed 57.5 0.79
60	65	5	97	cement. Rock hard. good return							62.5 0.85
65	70	5	95		WEAK	65.0-70.0 HORNBLENDE QUARTZ DIORITE as above but texture more variable due to increase veining and associated alteration envelopes.	65.0-70.0 Iron oxide minor carbonate on some fractures. Vuggy fine-grained diffuse epidote alteration around healed	68	5.5	7.5 hr. since circulation equilibrated after 3 hr. (Kuster element 11852)	66.8 0.73
70	75	5	85	70.0 m lost circulation Broken with sandy fault zones.	FAULTS	70.0-80.0 broken HORNBLENDE QUARTZ DIORITE; texture and grain size variable. Generally unfoliated with diffuse grain boundaries. Chloriti-	fractures (3/m); potassic (orthoclase) alteration envelopes on minor siliceous veins (0.4mm)				70.7 0.56 74.0
75	80	5	?	some confusion with footage chips at 78.2 -92.0 could be out up to 1 m (too low)	WEAK, LOCAL TO	zation of hornblende. 71.2 minor fault 60° to C.A. 10 cm clay gouge. 75.0 minor fault; 7 cm granulated rock 50° to C.A.	70.0-80.0 iron oxide on fractures. Kaolinite assoc. with faulting and fractures. Chloritization of mafics. 1 set vert. fractures; strong set fractures @ 45° to C.A. blocky broken core with voids and limonite along fractures.				0.69 77.7 0.80

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)

Sheet 3 of 12

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
80	85	5	90	Broken rock	WEAK	WEAK	W		80.0-83.0 medium-grained QUARTZ DIORITE; increased competency. 83.0-83.6 Granulated and altered FAULT 45° to C.A. 83.6-88.2 Broken altered QUARTZ	80.0-83.2 variably silicified, healed epidote veins. Minor FeO and carbonate on fractures (5/m)				0.80 83.0 0.17
85	90	5	70	and fine sand	MOD	MOD	WEAK		DIORITE; crystal grains indistinct. Core frags less than 10 cm. 88.2 Hematite stained gouge (10 cm) 20° to C.A.	83.0-83.6 chlorite, clay 83.6-88.2 Gouge zones are hematite and kaolinite; fractures have coatings of earthy-red				85.8 0.33 89.3
90	95	5	85	Broken rock 93.5 lost circ. Advance P casing to 92.H casing	MOD	WEAK	ST		88.2-94.5 Weakly foliated QUARTZ DIORITE. Mafics clotted, qtz. and fs grains indistinct 92.7-93.1 shattered sheared, crumbly,kaolinized fault zone; light FeO stain.	hematite and limonite. Qtz-diorite, hard and variably altered(epidote silica,orthoclase) 88.2-95.0 moderate carbonate-chloritization	92	11.5	7.5 hr. since last circulation equilibrated after approx. 3 hrs. (Kuster 11852)	0.94 92.6 0.37 95.0
95	98	3	90	to 102	STRONG		WEAK		94.5-95.0 shattered,sheared, crumbly kaolinized FAULT ZONE; FeO stain	of mafics. Epidote healed fractures (2/m) Other fractures are dry with some FeO (no ppt.)				0.79
98	102	4	40	*triconed*					95.0-98.0 sheared, strongly-foliated QUARTZ DIORITE; Foliation 30° to C.A. 98.0-102.0 no core (triconed)	95.0-98.0 mafics strung-out and completely gone to chlorite; fizz with HCl (carbonate); feldspars weakly kaolinized.				98.0 triconed
102	105	3	95	broken rock					102.0-117.5 Variably altered QUARTZ DIORITE; weakly foliated to non-foliated. Numerous	102.0-117.5 Mafics				102.0 0.85 103.5 0.40
105	110	5	95	good water return.	MOD	MOD			fault zones (listed below); Fractures 2-4/m mainly parallel foliation. 103.4-104.5 crumbly fault gouge.	chloritized; groundmass variably siliceous epidote healed veins. Intermittent fault zones obliterate original rock type. Disintegrated to clay and FeO.				106.0 0.99 110.0

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)

Sheet 4 of 12

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
110	115	5	95		MOD	MOD	SI		111.3 crumbly fault gouge(10cm)					110.0 0.87 112.7 0.93
115	120	5	65	probable cave zone.	WEAK		SI MOD		116.4 crumbly fault gouge(15cm) 117.5-120.5 broken crumbly FAULT ZONE; original rock disintegrated. contact with volc. 30° to C.A.	117.5-120.5 FeO limonite hematite, MnO, kaolinite				115.7 0.42 117.8 0.00
120	125	5	90						120.5-138.5 DACITIC FELDSPAR PORPHYRY; pale-green aphanitic groundmass. Feldspar phenocrysts to 2 mm with kelyphitic rims.	120.5-138.5 Weak saussuritization; minor white carbonate veinlets (1/m). NOTE: marked decrease				121.3 0.61 124.3
125	130	5	97	126 install BOP. partial loss of circulation	(SAUSSURIZATION)				Indistinct chilled margins. Clean fractures 5-8/m	in surface oxidation effects below 122 m. Minor FeO on some fractures to 184 m	125.7	27.8	6 hr. static time. temperature equilibrated (Kuster element 11852)	0.94 129.7
130	135	5	90						Rock sample "79H2-137.7"					0.25 131.0 0.94 132.3 0.55
135	140	5	97		WEAK	WK			Contact fragmented. Attitude not clear. Indistinct layering in porphyry near contact 25° to C.A. 138.5-148.9 Medium-grained relatively unaltered relatively unfoliated QUARTZ DIORITE to DIORITE. Increased competency.	138.5-146 relatively fresh. Minor chlorite. Minor silicification. Fractures dry (3/m)				136.1 0.50 138.5 0.84

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)
Sheet 5 of 12

Depth (m) From	Depth (m) To	m.	% rec.	general hole conditions	Graphic log: Chl/Ep/Cal	Graphic log: SiO2/Ser	Graphic log: Kaolinite	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
140	145	5	100			WEAK							0.84
145	150	5	95	soft, broken	MOD	MOD / WEAK		148.9-153.0 sheared,brecciated DACITE(?) and FAULT GOUGE; shearing 40° to C.A.	146.0-148.9 contact effect. Increased silicification,chloritization. 148.9-153.0 original rock				147.2 / 0.76 / 149.2
150	155	5	85		WEAK	W	STRONG	153.0-168.0 pale-green altered PORPHYRY similar to ppy up section but feldspars altered emerald green and kaolinitiz-	mostly obliterated. Strong kaolinitization hematite. 153.0-168.0 phenocrysts altered dark green	152	48.5	6 hr. static time; temp equilibrated (Kuster element 11852)	0.20 / 153.2
155	160	5	90	soft,broken	MOD		MOD	ation of groundmass more intense. Fractures and faulting more prevalent (10-20/m) 154.0 minor fault 156.5 " 30° to C.A. 157.8 " 30° to C.A.	saussuritization; (chlorite,epidote, calcite zoisite);groundmass; gouge and minor veinlets (1-2/m) fizz with HCl; Weak kaolin-				0.12 / 157.0 / 0.65
160	165	5	90					160.2 " 45° to C.A. 162.0 " ? 163.0 " ? Rock sample "79H2-165.5"	itization,silicification of groundmass;sericite on fractures				161.7 / 0.23 / 163.5
165	170	5	90		ST / W		ST / WK	168.0-168.4 FAULT GOUGE slip 40° to C.A. crosscutting foliation in footwall;	168.0-168.4 chlorite carbonate, kaolinite gouge.	166	64.0	6 hr. static time Kuster chart trace slightly unstable due to mechanical problem; Temperature approximately correct.	0.66 / 167.9 / 0.85 / 169.7

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)
Sheet 6 of 12

Depth (m) From	Depth (m) To	m.	% rec.	general hole conditions	Graphic log: Chl/Ep/Cal	Graphic log: SiO2/Ser	Graphic log: Kaolinite	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
170	175	5	85		MOD		WEAK	168.4-179.9 sheared,altered, foliated QUARTZ DIORITE. foliation 25° to C.A. Fractures subparallel to foliation & shearing (5-8/m)	168.4-175.7 moderate to strong propylitic alteration. Mafics strung out and altered to chlorite;Feldspars partly				0.32 / 172.5
175	180	5	97	core soft	WEAK / ST	MOD		170.5-171.2 intense shearing 172.4 " " Rock sample "79H2-178.6" contact approx. 50° 179.9-184.0 creamy pale-green	altered to carbonate and kaolinite;carbonate ppt on some fractures. 175.7-178.7 Increase in competency due to sil-				0.91 / 179.1 / 0.42
180	185	5	95		WEAK			aphanitic RHYOLITE to RHYODACITE; flow banding evident at 50° to C.A. Rock sample "79H2 182.5" contact as volc breccia 20 cm to 50° to C.A.	icification and epidotization;gradational to; 178.7-180.0 Altered transition zone.Strong fine grained chlorite,				180.2 / 0.84 / 184.0
185	190	5	95		MOD / ST			184.0-187.1 Saussuritized pale-green DACITIC FELDSPAR PORPHYRY; zoned with increasing hematite (purplish colour) due to iron content downward. Rx sample "79H2-185.0"	epidote,calcite,hematite 180.0-184.0 Minor carbonate on some fractures. (3-5/m);calcite crystals 182.5 184.0-187.1 feldspar				0.86 / 187.1
190	195	5	97		WEAK			187.1-190.2 Altered foliated QUARTZ DIORITE gradational change to. 190.2-205.0 medium-grained, weakly foliated to non-foliated	phenocrysts altered emerald green and groundmass altered pale-green(epidote,chlorite, zoisite) Minor carb-				0.91
195	200	5	97		MOD / VWK	MOD		hornblende QUARTZ DIORITE 10 cm granulated zones at 196.4,196.8,197.6 Rock sample "79H2-199.8"	onate veinlets. 187.1-188.6 Strong chlorite epidote carbonate,hematite alteration. 188.6-196.1 mafics altered to chlorite epidote.Minor carbonate and calcite veinlets (1/m) Fractures clean (no ppt.) but generally fizz with HCl. 196.1-198.0 Mafics to chlorite-epidote. Feldspar to clay (mud) purplish calcite crystals on fracture 197.2 m				195.4 / 0.74 / 199.4

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.) Hole No. M7-79D (79H2)

Sheet 7 of 12

Depth (m) From	Depth (m) To	m.	% rec.	general hole conditions	Graphic Log Chl.Ep.Cal	Graphic Log SiO2.Ser	Graphic Log Kaolinite	Graphic Log Rock	Rock type, description, structure, fracture density	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
200	205	5	97		V. WEAK					198.0-205.0 Relatively fresh; Weak chloritization of mafics locally.				0.88 203.5 —
205	210	5	97		WK				205.0-223.4 Medium-grained, weakly foliated to non-foliated, hornblende QUARTZ DIORITE Contains minor sections of foliated quartz diorite coinciding with increasing degree of alteration. plag 40-45% qtz 10-15% hbl 30-35% bio 5-10% pyrite < 1%	205.0-223.4 Pervasive weak chlorite epidote of mafics. Contains minor short sections of increased epidotization + weak silicification. Minor qtz veins.	205.7	110±5	7½ hr. static time Temperature off-scale on low-temp. Kuster-probe (11852) 110°C estimated by mathematical extrapolation of Kuster curve.	0.88 207.7 — 0.87
210	215	5	97		WEAK									211.5 — 0.89
215	220	5	97											215.7 — 0.84 219.4 —
220	225	5	97						Contact 30° 223.4-233.3 saussuritized, pale green DACITIC FELDSPAR PORPHYRY. Size and density of phenocrysts variable. Contains rare zenoliths of similar but slightly darker volcanics. Rock sample "79H2-227.5"	223.4-233.3 Ground mass altered pale green (fine-grained chlorite, epidote, calcite) Fizzes with HCl. Minor carbonate veinlets. White, fine-grained, crystalline carbonate ppt. on open fractures near lower contact.				0.80 223.6 —
225	230	5	97		STR-MOD									0.85 227.7 — 0.94

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.) Hole No. M7-79D (79H2)

Sheet 8 of 12

Depth (m) From	Depth (m) To	m.	% rec.	general hole conditions	Graphic Log Chl.Ep.Cal	Graphic Log SiO2.Ser	Graphic Log Kaolinite	Graphic Log Rock	Rock type, description, structure, fracture density	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
230	235	5	97	30% return	MOD ST				lower contact broken. Some shearing at 40° to C.A. 233.3-283.0 Weakly foliated to non-foliated, medium-grained BIOTITE-HORNBLENDE QUARTZ DIORITE ;moderately fractured (5-10/m). Increased epidote-chlorite along healed slippage planes locally.	233.3-246 moderate propylitic alteration (chlorite, epidote, carbonate) mainly of mafic minerals. Fracture surfaces (±chlorite) generally fizz with HCl. Minor white powdery carbonate ppt. on some fractures. gradational change	233	163±5	8 hr. static time Temperature off-scale on medium-temperature element 163°C estimated by mathematical extrapolation of Kuster curve.	0.94 232.0 — 0.99 233.2 — 0.00 234.6 —
235	240	5	95											0.68
240	245	5	95		MOD									239.7 — 0.74 243.6 — 0.25
245	250	5	95							246-283 as above but with slightly weaker alteration. Same fracture density and ppt.				245.0 0.66 247.5 — 0.73
250	255	5	95		WEAK						253.7	155	7½ static time. Temperature with maximum registering thermometer.	251.2 — 0.72 255.3 —
255	260	5	97							257-274 earthy red hematite locally associated with fractures. Minor ilmenite with rare quartz veins (261.5, 262)				0.82 259.6 —

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)
Sheet 9 of 12

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
260	265	5	95								0.80 263.5
265	270	5	95		MOD	267-283.0 one set steeply dipping fractures (± ppt)					0.74 267.7 0.53 269.0
270	275	5	95		WEAK TO	Rock sample "79H2-268.0" (silica ppt)		271	158	7½ hr static time Temperature with maximum registering thermometer.	0.91 271.5 0.52 275.2
275	280	5	95								0.84 279.2
280	285	5	95			283.0-298.5 SHEARED QUARTZ DIORITE. as above but with marked increase in parallel fractures (10+/metre) and cleavage at about 45° to C.A.	283.0-298.5 moderate to strong propyl itic alteration. Increase in chlorite along cleavage planes. Carbonate precipitate crystalline and white powder on most fractures. (10 +/metre) Rare silica ppt.				0.94 283.3 0.57
285	290	5	90		MOD TO STR.						287.0 0.19

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)
Sheet 10 of 12

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
290	295	5			MOD TO STRONG						290.7 0.47 294.5
295	300	5			WEAK / WEAK	298.5-310.0 medium-grained, mainly unfoliated, BIOTITE-HORNBLENDE QUARTZ DIORITE; decrease in fracture density (5/m)	298.5-305.8 generally weak propyl itic alteration of mafics (chlorite,epidote,carbonate) Weak silicification; Contains secti ons of strong fine-grained chlorite-epidote-carbonate-clay alteration possibly ass. w. old shearing 22° to C.A. (302.4,302.9,304.9,305.6) Carbonate ppt's as before	296.9	176.7	8½ hr. static time, good equilibrium BHT with Kuster instrument,high temperature element 5385	0.59 298.3 0.82
300	305	5			ST / WK / WK / WK						302.0 0.86
305	310	5			ST / WK / V. WK						306.1 0.76
310	315	5		return about 50%	MOD	310.0-315.0 as above but with increased fracture density (10/m)	305.8-313.8 Weak propylitic alt'n of mafics (mainly chlorite) Fractures dry with no visible ppt. although a few fizz with HCl	311.0	179.6	8½ hr. static time Equilibrated BHT with Kuster element 5385.	310.6 0.48 314.1
315	320	5		315.7 15+ metres cave in hole on bit change	ST / WK MOD / WK	315.0-317.5 alt'n obscures original rock textures. 317.5-324.8 medium-grained, unfoliated, siliceous QUARTZ DIORITE;fractures 5-10/m	313.8-317.5 Strong chlorite -epidote-carbonate-hematite + clay alt'n;shearing 25° to C.A. Carbonate & minor silica ppt on fractures (5-7/m) 317.5-324.8 weak chlorite epidote alt'n of mafics. pervasive weak to moderate silicification;	316.7	175.7	9½ hr. static time. Equilibrated BHT with Kuster element 5385.	0.80 317.8 0.73

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)

Sheet 11 of 12

DRILLING LOG Depth (m) From	To	m.	% rec.	general hole conditions	GRAPHIC LOG (Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock)	GEOLOGICAL LOG Rock type, description, structure, fracture density	Alteration, veins, precipitates	GEOPHYSICAL LOG Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
320	325	5			WEAK / MOD	gradational to 324.8-326.5 original textures obscured, broken contact with	siliceous veins ass.w. epidote;Minor qtz-carbonate ppt. gradational to: 324.8-326.5 strongly				0.73 322.1 0.44
325	330	5			W / S WEAK	326.5-367 medium-grained, unfoliated, HORNBLENDE (±BIOTITE) QUARTZ DIORITE. Fractures uniform density at 3-4/m	altered to carbonate, kaoline,chlorite,relict igneous texture 326.5-367.0 weak propylitic alt'n. White	329.0	185.1	8½ hr. static time	326.2 0.15 tube mislatch 329.0
330	335	5					scaley precipitate on some fractures (2/m) partly carbonate but also an unidentified soft component (clay?)			Equilibrated BHT with Kuster element 5385	0.73 332.0 0.97
335	340	5				Mode: 40% plagioclase	White carbonate on other fractures (powder and minor veinlets.)				336.2 0.98
340	345	5		rock "exceptionally" hard	WEAK	25% quartz 28% hornblende 5% biotite 1% chlorite 1% accessories		343.0	188.0	7½ hr. static time Equilibrated BHT with Kuster element 5385.	340.3 0.90
345	350	5				<1% pyrite Rock sample "79H2-347.0"					

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M7-79D (79H2)

Sheet 12 of 12

DRILLING LOG Depth (m) From	To	m.	% rec.	general hole conditions	GRAPHIC LOG (Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock)	GEOLOGICAL LOG Rock type, description, structure, fracture density	Alteration, veins, precipitates	GEOPHYSICAL LOG Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
350	355					as above	as above	353.0	186.9	7½ hr. static time Equilibrated BHT with Kuster element 5385	0.90 352.7 0.75
355	360				WEAK						356.5 0.95
360	365					363-367 weak foliation 50° to C.A.		364.0	188.6	9½ hr. static time Equilibrated BHT with	360.5 0.85 365.0
365	367							367	192.7	Kuster element 5385 16 hr. static time Equilibrated BHT with Kuster element 5385	0.69 367.0
			END OF HOLE								

NOTES: Last drilling shift was night shift Nov. 29.

Dec 4: Water test: pressured with water thru H casing (at 102m) with BOP open to 50 psi; leaked out annulus between P&H casing

Dec 5: Water test: with BOP pipe rams closed on 15 metres of H rods; pressured thru H rod (whole hole) to 30 psi, 50 psi, 70 psi, 90 psi, 110 psi, - (Ian Blown) Expl. Dept. reamed out hole in prep for temperature traverse - "70 metres cave" at bottom; approx. 2 hrs circulation

Dec 6: Post-drilling temperature profile (see table). BHT at 367 metres heated up to 202.2°C.

COMPLETION: Lined with 2-inch threaded and coupled pipe fitted with 2-inch gate valve at the collar. Bottom 180 feet of liner perforated with a two 3/8 inch holes at 10 feet intervals.

APPENDIX B-6

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET.

Hole No. M8-79D (79H3)
Sheet 1 of 10

Project Location Meager Creek-South Reservoir Co-ordinates 5601 870N; 461 630 E Collar elevation 875 m. (2870 ft.)

Date Started November 9,1979 Date Completed December 16,1979 Total Depth 290.4 m. Type/Size of Bits HQ

Drilling Contractor BC Hydro-Construction Division Drilling Section Geologic Log By BDF Geophysical Log By BDF, JFR

General Summary Comments

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO_2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
0	10	10	-						overburden					
10	11.5	1.5	0						triconed					11.5
11.5	15	3.5	85	PW casing to 10 m. HW casing to 12.5 m.	WEAK				11.5-39.0 Broken fine to medium-grained, grey, BIOTITE HORNBLENDE QUARTZO-FELDSPATHIC GNEISS Gneissocity 35-40° to C.A.	11.5-28.5 Minor weak propylitic alteration, silicification locally, weathering and oxidation prominent along fractures and faults.				
15	20	5	90	no return	VERY WEAK					Minor carbonate stringers. Minor chlorite on some slip surfaces.				0.56

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M8-79D (79H3)
Sheet 2 of 10

DRILLING LOG					GRAPHIC LOG				GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal	SiO_2,Ser	Kaolinite	Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
20	25	5	80		W / ST / V. WK	W / WK	ST		21.2-21.7 FAULT clay-rich fault gouge. Sharp upper gouge/rock interface at 35° to C.A. cutting foliation.	21.2-21.7 buff green clay, carbonate, chlorite, gouge.				21.0 / 0.30 / 24.0
25	30	5	80	hard and broken	S / V WK / V WK / W	WK	W / W		25.3-25.7 FAULT; granulated rock and gouge 29.8-30.0 FAULT granulated and fragmented rock.	25.3-25.7 white powdery clay-carbonate and medium-green chlorite 28.5-36.0 Moderate silicification (± minor	25	5.2	16 hr. static time Wier-Jones probe (down in morning with ½ hr. on bottom).	0.04 / 27.0 / 0.52 / 28.5
30	35	5	85			MOD				epidote) imparts finer-grained texture locally. 29.8-30.0 dark grey green chlorite-clay-carbonate alt'n assoc.				0.37 / 32.7 / 0.29
35	40	5	85	no return	MED				39.0-43.4 Pinkish-buff, very fine-grained, hard, brittle, fractured FELSITE.	w. fault. 36.0-39.0 softer rock; increased chlorite and carbonate in hanging wall, contact zone.	39	5.4	16 hr. static time Wier-Jones probe	37.5 / 0.30 / 40.5
40	45	5	75	lost water zone	ST		ST		43.4-44.7 FAULT gouge. 44.7-77.5 Uniform medium-grained, grey BIOTITE HORN-BLENDE QUARTZO-FELDSPATHIC	39.0-43.4 Minor carbonate stringers. HCl fizz on some dry fractures. 43.4-44.7 FeO, kaolinite carbonate gouge. 44.7-77.5 Carbonate and				0.24 / 44.7
45	50	5	90						GNEISS; marked increase in competency (5-7 fractures/m)	iron oxide on some fracture surfaces.	47	5.6	15 hr. static time Wier-Jones probe	0.85

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M3-79D (79H3)
Sheet 3 of 10

DRILLING LOG: Depth (m) From	To	m.	% rec.	general hole conditions	GRAPHIC LOG: Chl,Ep,Cal	SiO_2,Ser	Kaolinite	Rock	GEOLOGICAL LOG: Rock type, description, structure, fracture density.	Alteration, veins, precipitates	GEOPHYSICAL LOG: Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
50	55	5	95	no return				~	52.0 Rock sample "79H3-52.0"					52.5 — 0.85
55	60	5	95					~	foliation consistently 40-45° to C.A.					57.0 — 0.71
60	65	5	90		WEAK	WEAK		~						64.5 —
65	70	5	95		VERY	VERY		~	mode: 25% feldspar 30% quartz 25% biotite 18% hornblende 2% muscovite <1% pyrite		66	6.1	15 hr. static time Wier-Jones probe	0.65 70.3 —
70	75	5	95					~						0.78 74.8 —
75	80	5	95		WK TO MOD			~	77.5-88.5 transition zone of GNEISS (as above) to AMPHIBOLITE. Gneissic rock with increased biotite and planar fabric contains short sections of dark green AMPHIBOLITE.	77.5-88.5 Weak to moderate chlorite alt'n of biotite and hornblende; dark green chlorite plus carbonate fizz on fractures.				0.82 79.0 —

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M3-79D (79H3)
Sheet 4 of 10

DRILLING LOG: Depth (m) From	To	m.	% rec.	general hole conditions	GRAPHIC LOG: Chl,Ep,Cal	SiO_2,Ser	Kaolinite	Rock	GEOLOGICAL LOG: Rock type, description, structure, fracture density.	Alteration, veins, precipitates	GEOPHYSICAL LOG: Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
80	85	5	95					~		local silicification and fine-grained epidote.	80.7	6.5	15 hr. static time Wier-Jones probe.	0.43 84.2 —
85	90	5	90					~	sharp(fault ?)break to : 88.5-98.2 soft,strongly altered,broken AMPHIBOLITE(?) original texture obscured; ~~shearing locally imparts planar~~ fabric.	88.5-98.2 Completely altered to kaolinite chlorite,milky white ~~carbonate~~ siderite and minor reddish hematite. Strong fizz with HCl. 93.0 minor milky quartz				0.87 88.5 —
90	95	5	70		STRONG		STRONG						Wier-Jones probe U.S. reading attempted but unsuccessful	0.06 94.0 —
95	100	5	75						gradational change to: 98.2-120.5 broken and faulted, dark green-grey, AMPHIBOLITE and minor GNEISS. Disseminated pyrite to 2%. Slightly magnetic. 102.7 minor fault Rock sample "79H3-106.0" cleavage 45° to C.A. 107.0 minor fault	98.2-120.5 Rock well altered: pervasive dark sea-green chlorite, local strong epidote, lesser carbonate, local weak silicification. Carbonate fizz on some fractures and strong (with chlorite)in fault zones. fine crystalline epidote;magnetite,minor quartz ppt.				0.22 96.7 — 0.13 98.4 — 0.41 99.7 —
100	105	5	75		STRONG								Wier-Jones probe U.S. no reading obtained.	0.23 103.7 — 0.59 105.0 —
105	110	5	80		VERY									0.06 107.0 — 0.29 108.5 —

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.) Hole No. M8-79D (79H3)

Sheet 5 of 10

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
110	115	5	75		STRONG	114.0 minor fault; chlorite carbonate gouge. 114.9 minor fault; chlorite carbonate gouge.					0.64 110.5 0.14
115	120	5	75		VERY	118.8 minor fault	Composition almost all mafic minerals. Rock soft with very strong chlorite alteration.				116.0 0.41 119.0
120	125	5	75	no return rock broken	EXTREME / STRONG	120.5-125.7 Soft, completely altered FAULT GOUGE and FAULT BRECCIA. Breccia is rounded, ragged, altered rock fragments in clay gouge.	Minor qtz veins. 120.5-125.7 Completely altered to chlorite carbonate, clay. Pyrite to 10% locally.				0.09 125.7
125	130	5	85		MODERATE	125 .7-132.2 siliceous GNEISS; dark grey, fine to medium-grained. Slight increase in competency.	125.7-132.2 moderately silicified. Minor white quartz veins (one is 3 cm. wide) ~~parallel to foliation~~ at 40° to C.A. Carbonate flakes on some fractures.				0.82 128.8 0.51
130	135	5	75	rock soft		gradual change to 132.2-168.0 AMPHIBOLITE and streaky AMPHIBOLITE. Texture from fine to coarse-grained.	132.2-168.0 Hornblende variably altered to				131.2 0.20 134.8
135	140	5	75		MODERATE / WEAK	Layering and banding locally of dark-greenish hornblende rich layers with layers containing up to 30% feldspar. Well fractured (15+/m)	chlorite; minor carbonate local weak silicification; white carbonate precipitate on some fractures.				0.63 138.0 0.00 139.7

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.) Hole No. M8-79D (79H3)

Sheet 6 of 10

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
140	145	5	80			140.8 minor chloritic FAULT gouge.		142	5±(?)	Wier-Jones probe repaired but reading not steady.	0.21 142.5 0.60
145	150	5	70	tube mislatch @ 147 m.		Rock sample "79H3-147.5"	153-165 Granular epidote and white flakey ~~carbonate alteration~~ assoc. with fractures.				145.5 0.29 tube mislatch 147.0 0.83 148.5
150	155	5	80		MODERATE / WEAK	151.7 minor FAULT					0.26 152.5 0.46 155.5
155	160	5	90								0.39 158.6
160	165	5	90			cleavage and banding 45° to C.A.	165-168 moderately silicified and fine-grained.				0.37 163.5 0.47
165	170	5	90		WEAK / MOD	gradational to: 168.0-207.0 Light grey, hard QUARTZO-FELDSPATHIC GNEISS (see over)	168.0-207.0 Pervasive weak to moderate silicification, (over)				166.5 0.75 169.5

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
170	175	5	90	no return		-mainly quartz/feldspar, (65-70%), biotite, hornblende (30-35%). Fine-grained with grain boundaries fused and indistinct.	very minor chlorite alt'n of mafics; carbonate and minor chlorite on fractures. strong alteration	171	11.5	Wier-Jones probe repaired. Good check with maximum registering thermometer 8 hr. static time-½ hr. on bottom. Water level	171.0 0.24 0.85 173.6
175	180	5	80		WEAK / MODERATE	Moderately fractured (7-10/m) and faulted (1/5 m) Minor faults (173.9;174.5,	locally at faults:			at 40 m.	0.48 177.7 0.75
180	185	5	90	hard, broken rock with badly crumbled seams.	VERY WEAK TO	181.5, 186.0, 188.0) Gneissocity 50° to C.A.					181.0 0.65 183.2
185	190	5	85	187.5 ream HW casing 12.5 to 47 m. (still no				187.5	14.0	Wier-Jones probe U.S. Temperature by max. registering thermometer lowered with W-J probe	0.61 193.0 0.0 194.3
190	195	5	80	return)	ST / ST	193.0-194.0 FAULT				static time 8 hr. ½ hr. on bottom Water level at 40 m.	0.78 198.6
195	200	5	90		WK TO MOD	Rock sample "79H3-196.5"					0.47 202.5 0.81

DRILLING LOG					GRAPHIC LOG	GEOLOGICAL LOG		GEOPHYSICAL LOG			RQD
Depth (m) From	To	m.	% rec.	general hole conditions	Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	
200	205	5	95	no return	WK TO MOD						202.5
205	210	5	90		WK TO MOD	0.5 m fault zone followed by: 207.0-227.5 light-grey FELDSPAR PORPHYRY. Feldspar (and lesser quartz) phenocrysts to 5 mm are ragged and part-	207.0-227.5 Feldspar phenocrysts altered to clay and carbonate (commonly preferentially				0.81 207.0 0.87
210	215	5	95		MODERATE (CARBONATE)	ially altered clay carbonate) Groundmass aphanitic. Xenoliths of darker green but similar volcanic are common in irregular shapes up to	over groundmass). Groundmass moderately altered to clay (?) and carbonate(fizz with HCl) Carbonate (with rare				211.5
215	220	5	95		MODERATE	8-10 cm across. Rock porous (soaks up water). Rock sample "79H3-211.5"	SiO_2) precipitates on fractures (3/m).				0.86
220	225	5	95								219.0 0.89
225	230	5	85	soft muddy rock (no cave) no return.		227.5-231.5 FAULT; 25° to C.A. (upper contact) Altered shear zone; Original textures destroyed.	227.5-231.5 Rock completely altered to clay, carbonate, chlorite, hematite, silica.				227.7 0.25

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M8-79D (79H3)

Sheet 9 of 10

Depth (m) From	Depth (m) To	m.	% rec.	general hole conditions	Graphic Log (Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock)	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
230	235	5	90			231.5-244.8 dark sea-green, medium-grained hornblende-rich (80 plus %) AMPHIBOLITE. Fractures 3/m	231.5-244.8 Weak chlorite alt'n of hornblende. Local weak fizz with HCl. Cut by carbonate				0.25 231.5
235	240	5	95		WEAK	Rock sample "79H3-239.5"	and quartz veinlets (10 plus/m) and some quartz veins.				0.89
240	245	5	95	soft rock		contact 50° to C.A. 244.8-259.1 alternating grey medium-grained GNEISS and green, banded AMPHIBOLITE.	244.8-259.1 Weak chlorite, carbonate alteration of mafics.	244.5	22.0	maximum registering thermometer in Kuster water bailer.	244.5
245	250	5	70		WEAK MOD / WK	Banding subparallel to gneissocity and contacts at 30° to C.A. 248-250.5 broken core minor faults 248,249,257.7.	Strong chlorite-epidote carbonate-hematite alt'n locally assoc. with minor shearing. Carbonate and silica			8 hr. static, ½ hr. on bottom	0.71 248.2
250	255	5	90		MOD	Rock sample "79H3-251.0"	precipitate on fractures (5-7/m). Minor quartz veinlets.				0.31 251.0 0.94 254.7
255	259.1	4.1	90		WK TO MOD			259.2	25.5	max. registering thermometer 8 hr. static, ½ hr. on bottom	0.48 256.4 0.64 259.0

NEVIN SADLIER-BROWN GOODBRAND LTD. - GEOTHERMAL TEST HOLE LOG SHEET (Cont.)

Hole No. M8-79D (79H3)

Sheet 10 of 10

Depth (m) From	Depth (m) To	m.	% rec.	general hole conditions	Graphic Log (Chl,Ep,Cal / SiO2,Ser / Kaolinite / Rock)	Rock type, description, structure, fracture density.	Alteration, veins, precipitates	Depth(m)	T°C	Comments, hole bottom, hours since circulation.	RQD
259.1	290.4	31.3		rock harder		no detailed log available (core remains at site)		268.1	26.8	Kuster probe 11852 8 hr. static ½ hr. on bottom	
	290.4	END OF HOLE									
				Completion notes:		Rods pulled, casing left in place in anticipation of deepening hole Approx. 7 boxes of core remains at the site.					

APPENDIX B-7: Summary of BHT Data for Drill Hole M6-79D, South Reservoir, Meager Creek Geothermal Project

Date 1979	Hole Depth (m)	Temperature (°C)	Temperature Probe	Static Time (hrs)	Static Water Level (m)	Comments
9/8	72.5	41.4	K11852	2		First run with Kuster system. Hole making water near 60m.
10/8	104.0	71.3	K11852	7.5		Good equilibrium curve.
11/8	123.5	79.0	K11852	7.5		Good equilibrium curve.
12/8	143.0	85.2	K16351	9.25		Temperature still rising on chart hole now cased to 69.2m.
14/8	162.5	90.4	K16351	7.5		Good equilibrium curve.
15/8	179.0	76.8	K16351	7.5		Good equilibrium curve.
16/8	204.5	117.1	K16351	7.5		Almost equilibrium temperature.
17/8	215.0	132.2	K16351	7.5	70	Good equilibrium curve (see appendix for reproduction of this curve).
19/8	231.5	140.8	K16351	34	70	Run with 24 hr. Kuster clock stepped hole traverses run at this time.
21/8	239.0	140.3	K16351	15		Good equilibrium curve. Highly fractured rock intersected return fluids lost.
20/9	282.0	132.3	K16351	8	150	Good equilibrium curve, test run in BQ rods.
28/9	318.0	131.0	K16351	8	150	Good equilibrium curve, test run in BQ rods.
4/10	321	-	K16351	8	-	Final stepped hole traverse run. Instrument jams at 312m. Bottom of hole not reached.

Note:
K = Kuster temperature element (followed by serial number).
MRT = Maximum Registering Thermometer (mercury constriction type).
T = Thermistor probe with digital surface readout.

APPENDIX B-7: Summary of BHT Data for Drill Hole M7-79D, South Reservoir, Meager Creek Geothermal Project

Date 1979	Hole Depth (m)	Temperature (°C)	Temperature Probe	Static Time (hrs)	Static Water Level (m)	Comments
29/10	68.0	5.5	K11852	7.5		Equilibration immediately.
30/10	92.0	11.5	K11852	7.5		Good equilibrium curve.
9/11	125.7	27.8	K11852	4.5		Good equilibrium curve.
14/11	149.5	48.5	K11852	6.0		Good equilibrium curve.
15/11	166.0	64.0	K11852	6.0	50	Ragged rebound curve indicates flow of cooler water into the hole.
16/11	205.7	110	K11852	7.5	50	Temperature element off-scale. Temperature estimated by extrapolation.
16/11	221.0	94	MRT	0.5	50	Thermometer within Kuster housing. Reading discounted because of insulating effect of Kuster housing and because of short static time.
17/11	233.0	163	K20108	7.5	50	Temperature element off-scale. Temperature estimated by extrapolation.
17/11	240	115	MRT	0.5	50	Thermometer within Kuster housing. Reading discounted because of insulating effect of Kuster housing and because of short static time.
18/11	253.7	115	MRT	8.0	50	Thermometer inside water bailer (ie. in contact with water). Temperature probably conservative.
19/11	271.7	158	MRT	8.0	50	As above.
20/11	296.9	176.7	K5385	9.0	50	Good equilibrium curve.
21/11	311.0	179.6	K5385	9.0	50	Good equilibrium curve.
22/11	316.7	175.7	K5385	9.0	50	Good equilibrium curve.
23/11	329.0	185.1	K5385	8.5	50	Good equilibrium curve.
27/11	343.0	188.0	K5385	7.5	50	Irregular equilibrium curve suggests cool water inflow.
28/11	353.0	186.9	K5385	7.0	50	Good equilibrium curve.
30/11	364.0	188.6	K5385	9.0	50	Good equilibrium curve.
1/12	367.0	192.7	K5385	16.0	50	Good equilibrium curve.
6/12	367.0	-	K5385	120.0	50	Stepped hole traverse run highest temperature at bottom of hole = 202.2°C.

Note:
K = Kuster temperature element (followed by serial number).
MRT = Maximum Registering Thermometer (mercury constriction type).
T = Thermistor probe with digital surface readout.

APPENDIX B-7 (cont'd): Summary of BHT Data for Drill Hole M8-79D, South Reservoir, Meager Creek Geothermal Project

Date 1979	Hole Depth (m)	Temperature (^{o}C)	Temperature Probe	Static Time (hrs)	Static Water Level (m)	Comments
15/11	25.0	5.2	T	16.0		
16/11	39.0	5.4	T	16.0		
17/11	47.0	5.6	T	16.0		
21/11	66.0	6.1	T	16.0	40	
22/11	80.7	6.5	T	16.0	40	
28/11	142.0	5±1	T	16.0	40	Thermistor probe cable develops intermittent open circuit.
2/12	171.0	11.5	T	8.0	40	
3/12	187.5	14.0	MRT	8.0	40	Thermistor probe cable develops permanent open circuit. Thermometer wired to outside of thermistor probe.
11/12	244.5	22.0	MRT	8.0	40	Thermometer lowered in Kuster water bailer. Hole now cased to 47.0m.
12/12	259.2	25.5	MRT	8.0	40	As above
13/12	268.1	26.8	K11852	8.0	40	Good equilibrium curve.

Note: K= Kuster temperature element. (followed by serial number).
MRT= Maximum Registering Thermometer (mercury constriction type).
T= Thermistor probe with digital surface readout.

APPENDIX B-8

M6-79D Post-Drilling Traverse Data

Traverse 1, August 19, 1979 Temperature Element 11852 Element Range 40-200°F Hole Depth 231.5 m		Traverse 2, August 19, 1979 Temperature Element 16351 Element Range 90-330°F Hole Depth 231.5 m		Traverse 3, October 4, 1979 Temperature Element 16351 Element Range 90-330°F Hole Depth 321.0 m	
Depth (m)	Temperature (°C)	Depth (m)	Temperature (°C)	Depth (m)	Temperature (°C)
0.0	15.4	152.4	51.5	205	105.3
15.24	18.6	167.6	59.0	210	113.2
30.48	21.9	182.9	64.0	215	116.3
45.72	25.8	198.2	95.3	220	122.6
60.96	33.9	213.4	115.3	225	126.9
76.20	34.5	231.7	137.4	230	129.1
91.44	36.7			235	132.6
106.68	38.9			240	134.6
121.92	42.5			245	135.7
137.16	47.8			250	133.1
152.40	53.4			255	126.3
167.64	61.1			260	127.8
182.88	66.4			265	133.8
				270	136.0
				275	137.4
				280	137.5
				285	136.9
				290	136.6
				295	136.2
				300	135.9
				305	133.5
				310	135.3

APPENDIX B-8

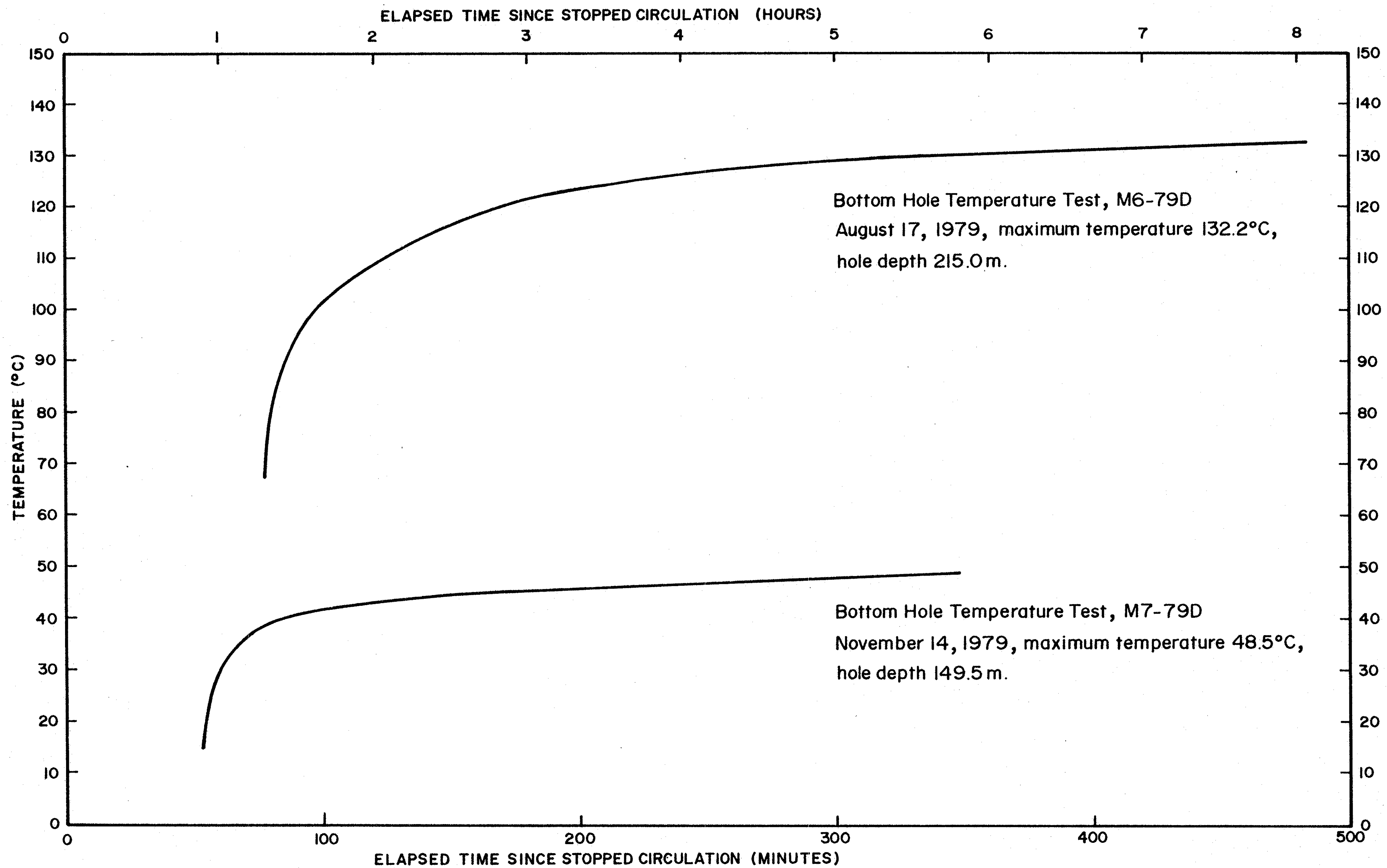
M7-79D Post-Drilling Traverse Data

Traverse 1, December 6, 1979
Temperature Element 11852
Element Range 160-338°F
Hole Depth 367.0 m

Depth (m)	Temperature (°C)
10	0.0
20	0.0
30	0.6
40	1.7
50	3.0
60	4.1
70	8.0
80	10.8
90	14.1
100	20.4
110	24.0
120	29.0
130	34.1
140	39.9
150	47.9
160	56.7
170	65.5
180	75.3
190	87.1
200	offscale 95

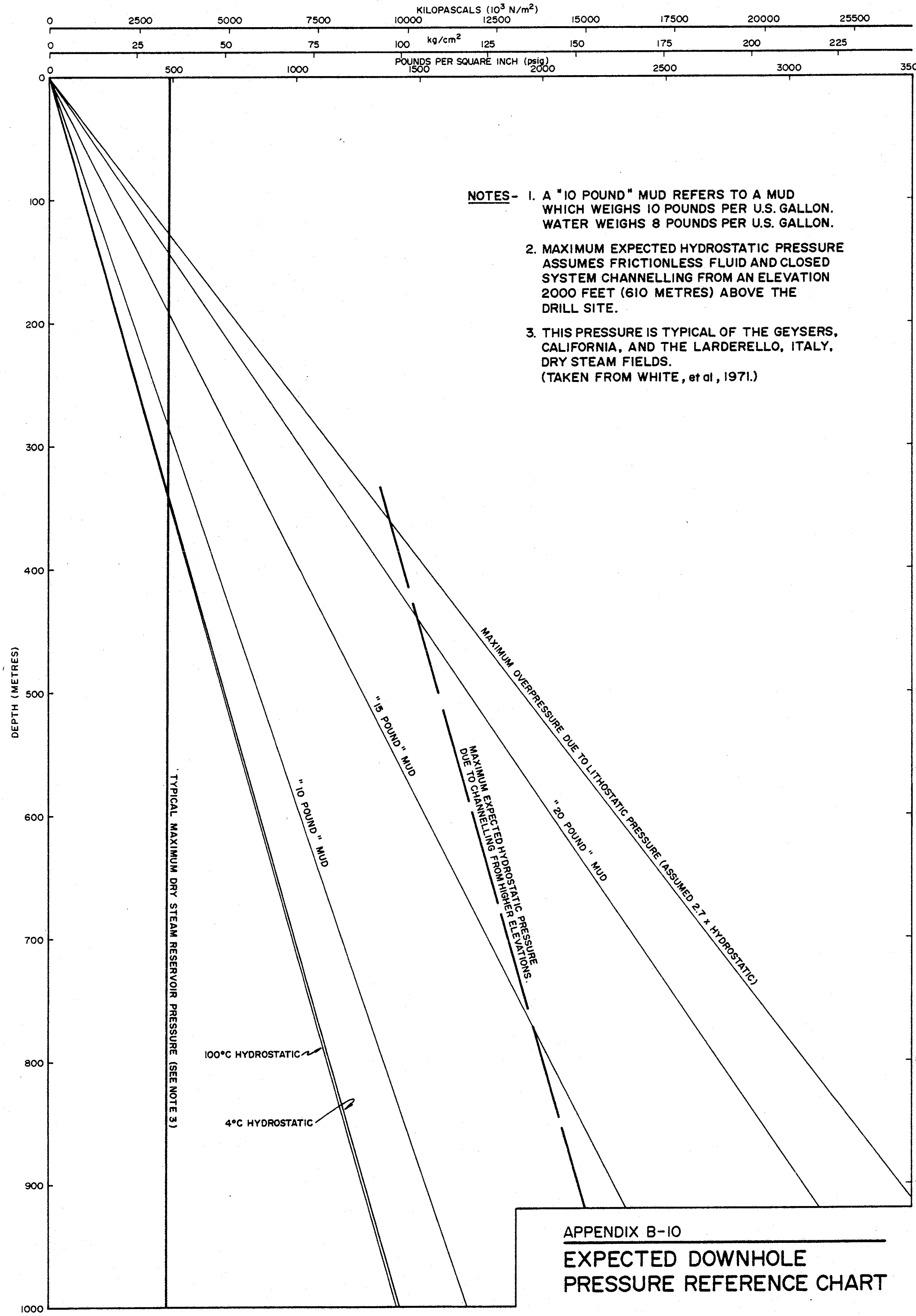
Traverse 2, December 6, 1979
Temperature Element 16295
Element Range 167-439°F
Hole Depth 367.0 m

Depth (m)	Temperature (°C)
200	110.2
210	123.3
220	132.9
230	143.2
240	154.0
245	159.8
250	163.7
255	167.5
260	168.3
265	168.6
270	171.6
275	174.4
280	177.5
285	180.8
290	183.5
300	191.6
305	194.2
310	195.7
315	196.6
320	197.5
325	198.1
330	198.8
335	199.8
340	200.2
345	200.6
350	200.9
355	201.1
360	201.5
365	201.9
367	202.2



APPENDIX B-9

TYPICAL BOTTOM HOLE TEMPERATURE RECOVERY CURVES AFTER CIRCULATION OF DRILLING FLUID HAS STOPPED. CURVES ARE REPRODUCTIONS OF KUSTER PROBE CHARTS.



APPENDIX B-10

EXPECTED DOWNHOLE PRESSURE REFERENCE CHART

APPENDIX C - GEOLOGY

APPENDIX C-1: LIST OF THIN SECTIONS

THIN SECTION NUMBER	COORDINATES	ROCK SUITE	DESCRIBED IN APPENDIX
79 ALT 01	5611 620; 458 920	QD	C-4
79 ALT 04	5608 530; 457 480	QD	C-4
79 ALT 08	5601 440; 460 080	QD	C-4
79 ALT 10	5609 480; 461 280	QD	C-4
79 ALT 14	5600 890; 462 950	QD	C-4
79 ALT 15	5600 880; 461 570	QD	C-4
79 ALT 16	5600 840; 462 650	QD	C-4
79 ALT 17	5603 560; 457 850	QD	C-4
79 ALT 18	5605 800; 459 120	QD	C-4
79 ALT 19	5604 720; 466 850	QD	C-4
79 ALT 20	5608 200; 467 670	QD	C-4
79 MEA 01	5601 682; 466 080	QD	C-4
79 MEA 02	5602 250; 466 540	QD	C-4
79H1-66.5	5602 280; 464 280	V	C-2
79H1-74.0	(M6 - 79D)	M	C-2
79H1-90.0	" "	V	C-2
79H1-184.6	" "	V	C-2
79H1-187.0	" "	V	C-2
79H1-208.5	" "	M	C-2
79H1-235.6	" "	M	C-2
79H1-258.5	" "	M	C-2
79H1-263.2	" "	V	C-2
79H1-281.0	" "	M	C-2
79H2-150.0	5601 850; 463 060	QD	C-4
79H2-255.5	(M7 - 79D)	QD	C-4
79H2-352.5	" "	QD	C-4
79H2-137.7	5601 850; 463 060	V	C-2
79H2-165.5	(M7 - 79D)	V	C-2
79H2-178.6	" "	QD	C-2
79H2-182.5	" "	V	C-2
79H2-185.0	" "	V	C-2
79H2-199.8	" "	QD	C-2
79H2-227.5	" "	V	C-2
79H2-268.0	" "	QD	C-2
79H2-347.0	" "	QD	C-2
79H3-83.0	5601 870; 461 630	QD	C-4
79H3-201.0	(M8 - 79D)	QD	C-4
79H3-256.5	" "	QD	C-4

APPENDIX C-1 (cont'd)

THIN SECTION NUMBER	COORDINATES	ROCK SUITE	DESCRIBED IN APPENDIX
79H3-52.0	5601 870; 461 630	QD	C-2
79H3-106.0	(M8 - 79D)	M	C-2
79H3-147.5	" "	M	C-2
79H3-196.5	" "	QD	C-2
79H3-211.5	" "	V	C-2
79H3-239.5	" "	M	C-2
79H3-251.0	" "	M	C-2

QD = Quartz diorite suite

M = Metamorphic suite

V = Hypabyssal dyke suite

APPENDIX C-2

PETROGRAPHY AND ALTERATION OF SAMPLES FROM 79H1,

MEAGER CREEK GEOTHERMAL AREA, BRITISH COLUMBIA

Peter B. Read

January 4, 1980

GEOTEX CONSULTANTS LIMITED CONSULTING GEOLOGISTS

PETROGRAPHY AND ALTERATION OF SAMPLES FROM 79H1, MEAGER CREEK GEOTHERMAL AREA, BRITISH COLUBMIA

1. INTRODUCTION:

This report is a petrographic examination of ten samples from hole 79H1 (UTM coordinates DM0464280E, DM5602280N) in the south reservoir area of Meager Creek Geothermal area, southwestern British Columbia. Half of the samples are metamorphic rocks (uKcm) of the amphibolite facies, which host highly altered hypabyssal intrusions that represent the remainder of the samples. In addition to a petrographic examination, the fine-grained mineralogy of the hypabyssal intrusions necessitated an X-ray diffraction examination (Appendix I). X-ray diffraction was performed on powdered but unheated or ungylcolated mounts of whole rocks so that clay mineral indentification is preliminary based on optical and some X-ray characteristics.

2. PETROGRAPHY AND ALTERATION:

The metamorphic rocks, samples 79H1-74.0, -208.5, -235.5, -258.5, and -281.0, range in composition from a biotite-bearing hornblende-plagioclase gneiss or streaky amphibolite to a biotitic quartzofeldspathic gneiss. These samples are from the western extension of unit uKcm exposed about 400 m to the southeast (Read, 1979). All of the metamorphic rocks have biotite, andesine, quartz, ±hornblende, ±epidote-clinozoisite as an assemblage which is compatible with the lower part of the amphibolite facies. These rocks are unfossiliferous and are correlated tentatively with the Cadawallader Group of Late Triassic age.

The hypabyssal intrusions, samples 79H1-66.5, -90.0, -184.6, -187.0, and -263.2, are all so highly altered that only quartz phenocrysts and a few cores of plagioclase phenocrysts remain. The intrusions are similar to and the same dike set as a southwesterly dipping dike of altered rhyodacite belonging to unit Pl of The Devastator Assemblage (*Ibid.*) which outcrops 150 m northeast of hole 79H1. The Devastator Assemblage is bracketed by K-Ar radiometric dating as being younger than 1.9 ± 0.2 Ma and older than 1.0 ± 0.1 Ma (*Ibid.*).

All rocks are modified to differing extents by low grade alteration assemblages. The metamorphic rocks have a propylitic assemblage of chlorite, calcite, epidote and albite which forms veins with alteration envelopes. Thin carbonate veins cut the propylitic assemblage and may be related to carbonate veins cutting the hypabyssal intrusions. Related to the carbonate veins is an assemblage of dolomite, calcite, "illite", "kaolinite", "montmorillonite" and quartz which obliterates the relict igneous mineralogy. In Meager Volcanic Complex, the carbonate-clay mineral assemblage characterizes The Devastator Assemblage and may mean that the alteration is 1.9 ± 0.2 Ma to 1.0 ± 0.1 Ma old and not necessarily part of the present geothermal system. The high grade regional metamorphic assemblage overprinted by a later propylitic alteration which was veined by a latest carbonate-clay mineral assemblage is similar to that found in other exploratory drill holes to the southeast of 79H1 (Read, 1975).

3. DETAILED PETROGRAPHY OF SAMPLES:

a. METAMORPHIC ROCKS:

1. Sample 79H1-74.0:

Medium grey, medium grained (1 to 3 mm), crudely foliated biotite (35%) hornblende (5%) quartz-plagioclase gneiss. Biotite is lusterous and unaltered as is 1% pyrite. One end of the sample is partly dull

dull grey-green possibly from alteration of biotite to chlorite along a fracture. The absence of layering in the eight centimetre length of core is insufficient evidnece to decide between an orthogneiss or a paragneiss.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Biotite (35%):

Pleochroic $\gamma = \beta$ = medium brown to α = light brown flakes with minor chlorite interleaved as an alteration product.

2. Hornblende (5%):

Small (0.5mm) subhedral prisms pleochroic from bluish green to olive green preferentially altered to chlorite and carbonate.

3. Plagioclase (49%):

Poikiloblastic porphyroblasts up to 1.5 mm in diameter filled with quartz inclusions. Grains are unzoned and rarely twinned. Flat stage plagioclase determinations give: $\perp X$, $Z \wedge (001) = 18^{\circ}$, $\perp X$, $Y \wedge (010) = 15^{\circ}$ = An_{32}.

4. Quartz (8%):

Granoblastic grains up to 0.8 mm in diameter and as very fine inclusions in plagioclase porphyroblasts.

5. Epidote-clinozoisite (3%):

Granoblastic grains scattered throughout.

6. Accessory Minerals:

(a) Apatite:

Small (< 0.1 mm) anhedral grains scattered throughout.

(b) Allanite:

A few grains pleochroic in shades of brown and rimmed by clinozoisite.

No sphene or zircon present.

Veins:

Late, thin (0.1 mm) veins of calcite.

The metamorphic mineralogy is consistent with the lower part of the amphibolite facies due to the presence of epidote and quartz, but otherwise it is noncritical. Later propylitic alteration affected mafic minerals locally replacing biotite with chlorite and hornblende with chlorite and carbonate. Calcite veins are the last event and do not have any associated wallrock alteration adjacent to them.

2. Sample 79H1-208.5:

Fine-grained (< 1 mm) biotite(20%) quartz-plagioclase gneiss. The 10 cm length of core lacks layering and may be either a para- or an ortho-gneiss.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (66%):

Rounded, poikiloblastic grains altered to epidote and muscovite. Flat stage plagioclase composition is: $\perp X$, $Z \wedge (001) = 13^\circ$, $\perp X$, $Y \wedge (010) = 11^\circ$ = An_{29}.

2. Epidote-clinozoisite (4%):

Colourless to pale greenish yellow grains up to 0.5 mm in diameter.

3. Biotite (20%):

Pleochroic $\gamma = \beta$ = dark chocolate brown to α = pale brown flakes up to 0.3 mm long and preferentially oriented to define a crude foliation.

4. Chlorite (2%):

Pleochroic $\gamma = \beta$ = medium green to α = pale green flakes which are length-fast with strong anomalous clove brown interference tints.

5. Muscovite (2%):

Randomly oriented flakes 0.1 to 0.3 mm long mainly in plagioclase porphyroblasts.

6. Quartz (5%):

Granoblastic, unaltered grains < 0.3 mm in diameter with slight undulatory extinction, neutral relief and uniaxial positive.

7. Accessory Minerals:

(a) Opaque Minerals (0.5%):

Scattered equant grains 0.1 mm in diameter.

(b) Apatite:

A few, small (< 0.05 mm) anhedral grains.

(c) Sphene:

A few scattered (0.1 mm in diameter) grains with characteristic optical properties.

Veins:

Hairline (0.05 mm thick) fractures filled with carbonate.

The metamorphic rock has a lower amphibolite facies mineralogy overprinted by a propylitic assemblage of chlorite, muscovite, carbonate and epidote which is in turn cut by thin carbonate veins.

3. <u>Sample 79H1-235.5</u>:

Fine-grained (1 mm), medium grey, streaky layered hornblende(30%) plagioclase(50%) gneiss, or as a field term - amphibolite.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Biotite (10%):

Pleochroic $\gamma = \beta$ = medium chocolate brown to α = pale brown flakes preferentially oriented parallel to layering. Flakes 0.1 to 0.4 mm long are locally altered to pale green chlorite.

2. Hornblende (30%):

Subidioblastic prisms up to 1.0 mm long with γ = bluish green, β = olive brown and α = pale olive brown. Pale green chlorite and carbonate are locally present along cleavage, and fine biotite flakes are spatially associated. About 5% of the hornblende is altered.

3. Plagioclase (47%):

Granoblastic, unzoned grains which are very slightly altered to carbonate plus muscovite. A few percent of the grains are untwinned and poikiloblastic with quartz inclusions. Flat stage composition determinations give: $\perp X$, $Z \wedge (001) = 18^\circ$, $\perp X$, $Y \wedge (010) = 14^\circ = An_{32}$; $\perp X$, $Z \wedge (001) = 26^\circ$, $\perp X$, $Y \wedge (010) = 20^\circ = An_{40}$.

4. Chlorite (3%):

Medium to pale green pleochroic flakes 0.3 mm long with anomalous clove brown interference tints and negative elongation.

5. Quartz (8%):

Granoblastic grains up to 0.5 mm in diameter, unaltered and slightly strained with undulatory extinction.

6. Epidote-clinozoisite (1.5%):

Small (0.2 mm in diameter) grains, pleochroic pale greenish yellow to colourless and spatially associated with mafic minerals

7. Accessory Minerals:

(a) Opaque Minerals (0.5%):

Equant grains 0.1 mm in diameter spatially associated with mafic minerals.

(b) Apatite:

A few anhedral grains scattered throughout.

No sphene or zircon.

Veins:

Chlorite or montmorillonite, carbonate and opaque minerals form veins 0.1 to 0.5 mm thick with radiating sheaves of calcite implying open space filling of the fracture.

The rock has a mineralogy compatible with metamorphism to the lower amphibolite facies which is weakly overprinted by a carbonate-chlorite-muscovite-epidote assemblage of propylitic alteration, and most recently by a chlorite or montmorillonite-carbonate-opaque mineral assemblage which fills fractures.

4. Sample 79H1-258.5:

Medium grained (1 to 2 mm) muscovite (5%) quartz plagioclase gneiss.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Muscovite (5%):

Present as coarse flakes up to 1.0 mm long and as fine (< 0.1 mm long) flakes, unoriented in plagioclase.

2. Plagioclase (65%):

Granoblastic grains dusted with alteration which locally includes randomly oriented muscovite flakes. Flat stage composition determinations give: $\perp X$, $Z\wedge(001) = 6^{\circ}$, $\perp X$, $Y\wedge(010) = 9^{\circ} = An_{12}$.

3. Quartz (30%):

Granoblastic grains up to 0.6 mm in diameter with weak undulatory extinction.

4. Garnet (2 grains):

Isotropic mineral of high positive relief and 0.1 mm in diameter.

Veins:

Hairline (0.05 mm thick) calcite veins.

The rock has a mineralogy which is consistent with the parent rock being a quartzo-feldspathic sandstone, but an orthogneiss is equally possible. The muscovite alteration and albitic composition of the plagioclase is consistent with the propylitic alteration present in all other metamorphic rocks in this hole. The calcite veins are most recent.

5. Sample 79H1-281.0:

Medium grey, well layered (1 to 10 mm thick) biotite (0.5%) hornblende (40%) plagioclase gneiss or amphibolite. A few fractures cutting the specimen have an irregularly developed light green zone of chlorite and epidote up to 5 mm thick surrounding the fractures.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (52%):

Granoblastic grains up to 0.7 mm in diameter which are unaltered and unzoned. Flat stage plagioclase composition determinations give: $\perp X$, $Z\wedge(001) = 25^{\circ}$, $\perp X$ $Y\wedge(010) = 23^{\circ} = An_{42}$; $\perp X$, $Z\wedge(001) = 27^{\circ}$, $\perp X$, $Y\wedge(010) = 21^{\circ} = An_{42}$.

2. Hornblende (40%):

Bluish green to olive brown pleochoric prisms up to 1.0 mm long which are unaltered except in the alteration envelope. Preferentially oriented to define layering and foliation.

3. Biotite (0.5%):

Small (< 0.1 mm) chocolate to pale brown pleochroic flakes.

4. Quartz (5%):

Granoblastic grains 0.3 mm in diameter, unaltered with slight undulatory extinction.

5. Opaque Minerals (2%):

Equant opaque grains 0.1 mm in diameter scattered throughout.

Vein:

Thin vein (0.2 mm thick) of calcite, chlorite and opaque minerals surrounded by a wallrock alteration envelope.

Alteration Envelope:

1. Plagioclase:

Partly altered to muscovite and epidote. Although no composition determinations are possible, the dusty and altered plagioclase has negative relief and is probably albite.

2. Epidote-clinozoisite:

Pale yellow green grains up to 0.5 mm in diameter.

3. Chlorite:

Medium to pale green pleochroic flakes up to 0.3 mm long with anomalous clove brown interference tints.

The amphibolite facies mineralogy of the rock is overprinted by a propylitic alteration assemblage of muscovite, chlorite, epidote, albite adjacent to a calcite-chlorite vein.

b. HYPABYSSAL INTRUSIONS:

1. Sample 79H1-66.5:

White, aphanitic rhyolite with large (up to 15 mm) irregular shaped lithophysae rich in quartz. The sample is a hypabyssal intrusion of the Devastator Assemblage.

Thin Section:

The following minerals are present:

1. Quartz:

Present as:

(a) Amygdule-filling in which the curved outline of grain boundaries and radiating layered inclusions suggest that the precursor to quartz was chalcedony and that it has been later recrystallized.

(b) As anhedral grains < 0.1 mm in diameter in matrix of hypabyssal intrusion.

2. "Illite":

Radiating sheaves of very fine colourless flakes with upper first order interference tints. X-ray diffraction characteristics are those of muscovite except that the (001) reflection has a height to width ratio measured at half peak height of 6.8 which is broad and considered by Carroll (1970) as one of the characteristics of illite.

3. Calcite and dolomite:

Untwinned granoblastic grains (< 0.1 mm) scattered throughout.

4. Plagioclase:

A few of the anhedral, 0.1 mm in diameter altered grains show albite twinning.

Veins:

Up to 0.4 mm thick of carbonate.

The rock is overprinted by an intense carbonate-clay mineral alteration.

2. Sample 79H1-90.0:

Medium grey-green porphyritic (5% plagioclase, 10% altered mafic minerals) felsic hypabyssal intrusion.

Thin Section:

The following minerals are present:

1. Quartz:

Present as:

(a) Anhedral grains pseudomorphing rectangular shapes which may have been former plagioclase phenocrysts.

(b) As grains overprinting lath-shapes of clay minerals and carbonate which represent original feldspar laths now pseudomorphed by carbonate, clay minerals and quartz.

2. Calcite and dolomite:

Fine granoblastic grains scattered throughout.

3. Plagioclase:

Euhedral phenocrysts up to 2.0 mm long which, although highly altered by calcite and clay minerals, still retains vestiges of albite twinning.

4. "Kaolinite" and "montmorillonite":

Replaces plagioclase and throughout matrix.

5. Apatite:

Thin prisms up to 0.4 mm long.

Veins:

Up to 1 mm thick of calcite and dolomite.

The original porphyritic intrusion has been extensively altered by carbonate and clay minerals and quartz.

3. Sample 79H1-184.6:

Light grey-buff, porphyritic (1% quartz, up to 2 mm, 20% plagioclase up to 4 mm) felsic hypabyssal intrusion. The plagioclase is randomly oriented and so highly altered that it retains only its euhedral outline but no trace of cleavage.

Thin Section:

The following minerals are present:

Phenocrysts:

1. Plagioclase:

Completely pseudomorphed by dolomite, "illite", and "kaolinite" in phenocrysts.

2. Biotite:

In phenocrysts up to 1.0 mm long completely pseudomorphed by muscovite and dolomite.

3. Quartz:

Rounded and embayed phenocrysts which are unaltered and up to 0.6 mm in diameter.

4. Apatite:

Large subhedral to euhedral prisms up to 0.5 mm long.

Matrix:

Consists of very fine grained (< 0.05 mm diameter) grains of quartz, "illite", "kaolinite", and dolomite.

Although a relict porphyritic texture remains, an intense carbonate-clay mineral alteration has replaced all but the quartz.

4. Sample 79H1-187.0:

White, aphanitic rhyolite, crackled with fractures with open space filling of carbonate.

Thin Section:

The following minerals are present:

1. Quartz (65%):

Very fine grains (< 0.05 mm) which have the form of recrystallized spherulites.

2. "Montmorillonite" and "illite" (25%):

In fine radiating sheaves which surround the quartz spherules.

3. Calcite and dolomite (10%):

Fine (< 0.1 mm in diameter) grains dispersed throughout rock.

Veins:

Up to 0.2 mm wide of calcite and dolomite.

The rhyolite is extensively altered by a carbonate-clay mineral assemblage which has preserved a micro-spherulitic texture pseudomorphed by quartz, but obliterated it wherever carbonate is present.

5. Sample 79H1-263.2:

Medium grey-green porphyritic (3% plagioclase) micro-spherulitic or -amygduloidal felsic hypabyssal intrusion.

Thin Section:

The following minerals are present:

1. Feldspar:

(a) As phenocrysts now totally pseudomorphed by carbonate and clay minerals, but a preferred orientation of what may have been laths defines a trachytic texture.

(b) One plagioclase phenocryst remains dusted with alteration products.

2. Calcite and dolomite:

Granoblastic grains permeating the rock.

3. "Kaolinite", "illite", and "montmorillonite":

Fine grained cloud throughout rock.

Veins:

Filled with calcite and dolomite.

The clay mineral-carbonate assemblage totally replaces the original igneous mineralogy of this hypabyssal intrusion.

4. REFERENCES:

Carroll, D. (1970):
Clay minerals: a guide to their X-ray identification; Geological Society of America, Special Paper 126, 80 p.

Read, P.B. (1975):
Drill core alteration and sinters, Meager Creek, British Columbia; unpubl. report to Nevin Sadlier Brown Goodbrand Ltd., 28 p.

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Geology, Meager Creek Geothermal area, British Columbia; Geological Survey of Canada, Open File 603.

APPENDIX I:

X-RAY DIFFRACTOGRAMS

(with original copy only)

APPENDIX C-3

PETROGRAPHY AND ALTERATION OF SAMPLES FROM

DDH 79H2 AND 79H3,

MEAGER CREEK GEOTHERMAL AREA, BRITISH COLUMBIA

Peter B. Read

March 14, 1980

GEOTEX CONSULTANTS LIMITED consulting geologists

PETROGRAPHY AND ALTERATION OF SAMPLES FROM DDH 79H2 AND 79H3 MEAGER CREEK GEOTHERMAL AREA, BRITISH COLUMBIA

1. INTRODUCTION:

This report is a petrographic examination of nine samples from DDH 79H2 (UTM coordinates DM043060E, DM5601850N) and seven from DDH 79H3 (UTM coordinates DM0461630E, DM5601870N) in the south reservoir area of Meager Creek Geothermal area, southwestern British Columbia. The holes were drilled in 1979 by British Columbia Hydro and Power Authority.

The two holes penetrate Mesozoic quartz diorite which hosts amphibolite and paragneiss of unit uЋcm (Read, 1979). and highly altered hypabyssal dikes of Pliocene to Recent age.

This report is preceded by a similar investigation of ten samples from DDH 79H1 (UTM coordinates DM0464280E, DM5602280N) (Read, 1980).

2, PETROGRAPHY AND ALTERATION:

(a) DDH 79H2:

Gneissic to random textured biotite, hornblende quartz diorite is exposed to within 200 m northeast of the collor of 79H2. Although radiometrically undated, the quartz diorite of unit Mqd (Read, 1979) must be older than the 81 Ma age of unit ιKqd which intrudes it. Amphibolite and biotite-quartz-plagioclase paragneiss septa within the quartz diorite may be correlative with the Cadwallader Group of Late Triassic age. The metamorphic rocks have mineral assemblages composed of biotite + quartz + plagioclase ± hornblende ± epidote which are compatible with metamorphism to the lower part of the amphibolite facies. Superimposed on this metamorphic assemblage is a chlorite + muscovite + epidote ± calcite propylitic alteration assemblage which affects all pre-Late Cretaceous units. A number of highly altered, porphyritic dykes, possibly related to rhyodacite of The Devastator Assemblage (unit P1 of Read, 1979) cut the plutonic and metamorphic rocks. Calcite, "clay minerals" and quartz pervasively alter the dikes and completely replace plagioclase and mafic phenocrysts. Veinlets of calcite cut all rock types and with the calcite + "clay mineral" + [1] quartz assemblage represent the youngest phase of hydrothermal alteration which may be related to the present geothermal system.

(b) DDH 79H3:

In DDH 79H3, massive and gneissic quartz diorite (unit Mqd) contain amphibolite layers (unit uKcm) and a slightly altered dike. The light grey porphyritic (hornblende, biotite, plagioclase) andesite is lithologically similiar to porphyritic andesite of unit P6i exposed on The Devastator. The age of unit P6i lies in the range of 0.5 ± 0.1 Ma to 0.1 ± 0.02 Ma. The plutonic and metamorphic rocks have the muscovite-chlorite-epidote-clacite propylitic overprint of probable Cretaceous age or older. Quartz veins cut this overprint. Calcite replaces some of the plagioclase in the andesite dike and calcite ± gypsum or anhydrite forms the youngest veins and replacements in plutonic and metamorphic rocks. Alteration of the andesite is younger than the interval 0.5 ± 0.1 Ma to 0.1 ± 0.2 Ma and places a maximum age on the calcite-"clay mineral"-gypsum-anhydrite alteration which may be related to the present geothermal system.

[1] The terms "clay minerals", "kaolinite" and "illite" are placed in quote marks because insufficient X-ray work was done for an assured unique clay mineral determination.

3. DETAILED PETROGRAPHY:

(a) Samples from DDH 79H2:

1. Sample 79H2-137.7 m:

Light grey, porphyritic (white feldspar, altered mafic minerals) andesite(?). Possibly a highly altered correlative of unit P6i.

Thin section:

The following minerals are present together with a visually estimated mode:

Phenocrysts:

1. Plagioclase (25%):

Subhedral to euhedral phenocrysts 1.0 to 2.0 mm long which are over 95% altered to calcite + "illite" + "kaolinite".

2. Biotite (?) (1%):

Pseudomorphs completely composed of calcite up to 1.0 mm long.

Matrix:

1. Plagioclase(?) (74%):

Anhedral grains < 0.03 mm in diameter which are partly altered to calcite + "illite" + "kaolinite".

Accessory minerals:

1. Apatite:

A dozen subhedral to euhedral grains up to 0.3 mm long.

2. Sample 79H2-165.5 m:

Light grey, porphyritic (quartz (1%), feldspar and mafic minerals 25%)) rhyodacite. Drill core sample has a medium grey, fine-grained but non-porphyritic inclusion up to 4 cm long in the felsite. Unit P1 (?).

Thin Section:

The following minerals are present together with a visually estimated mode:

Phenocrysts:

1. Biotite (3%):

Pseudomorphs up to 1.5 mm long which are completely pseudomorphed by muscovite-chlorite-calcite.

2. Plagioclase(25%):

Present as subhedral phenocrysts about 1.0 mm long which are partly replaced by calcite and "clay mineral". $\perp X$, $Z\wedge(001) = 11^\circ$, $\perp X$, $Y\wedge(010) = 14^\circ$ and $\perp X$, $Z\wedge(001) = 13^\circ$, $\perp X$, $Y\wedge(010) = 15^\circ$ = An_6 and An_4 (low temperature) respectively by flat stage plagioclase determinations.

3. Quartz (1%):

Rounded and embayed phenocrysts up to 1.5 mm in diameter which are unaltered.

Matrix (71%):

A very fine mixture (< 0.01 mm in diameter) of quartz, plagioclase, K feldspar (uncertain) and "kaolinite" and "illite".

Accessory Minerals:

1. Apatite:

Euhedral hexagonal prisms up to 0.2 mm long.

3. <u>Sample 79H2-178.6 m:</u>

Fine to medium grained (0.5 to 2 mm) medium grey, biotite, muscovite, chlorite quartz, plagioclase paragneiss. The core sample is cut by a single fracture surface coated with hematite.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Chlorite (3%):

Medium green to pale gree pleochroic flakes with anomalous clove brown interference tints, length-fast.

2. Biotite (10%):

Medium to pale brown pleochroic flakes 0.4 mm long.

3. Quartz (20%):

Anhedral grains < 0.6 mm in diameter which are unaltered.

4. Muscovite (5%):

Colourless flakes up to 0.2 mm long mainly within plagioclase as an alteration product.

5. Plagioclase (53%):

Present as large poikiloblastic rarely twinned grains 1 to 2.5 mm in diameter and as xenoblastic grains 0.1 mm in diameter. It is partly altered by carbonate and muscovite. No grains are suitable for composition determinations.

6. Epidote (15%):

Granular grains dominantly spatially associated with the mafic minerals.

Accessory Minerals:

1. Apatite:

Anhedral grains up to 0.1 mm in diameter

Veins:

Carbonate fills hairline fractures.

4. Sample 79H2-182.5 m:

White, aphanitic felsite cut by thin (1 to 3 mm thick) carbonate veins spaced 2 to 4 cm apart. The rock is probably related to unit P1 of The Devastator Assemblage.

Thin Section:

The following minerals are present together with a visually estimated mode:

Matrix (100%):

1. Quartz:

Fine (0.01 mm in diameter) anhedral, unaltered grains.

Alteration:

Calcite present as fine grains 0.01 to 0.8 mm in diameter which are poikiloblastic and enclose the quartz of the matrix. Fine "illite" scattered throughout the matrix completes the alteration assemblage.

Veins:

Calcite veins up to 1 mm thick.

5. Sample 79H2-185.0 m:

Light grey, porphyritic (feldspar and quartz) rhyodacite (?) probably related to 79H2-182.5 m and 79H2-165.5 m of unit P1 of The Devastator Assemblage.

Thin Section:

The following minerals are present together with a visually estimated mode:

Phenocrysts:

1. Quartz (1%):

Rounded and embayed phenocrysts about 0.8 mm in diameter which are unaltered.

2. Biotite (5%):

Flakes up to 1.2 mm long which are completely pseudomorphed by muscovite, calcite and dolomite.

3. Plagioclase (25%):

Subhedral phenocrysts 1 to 2 mm long which are completely pseudomorphed by calcite, dolomite and quartz.

Matrix (69%):

A fine grained mixture (< 0.02 mm in diameter) of quartz, calcite, dolomite,"illite" and "kaolinite".

Accessory Minerals:

1. Apatite:

Euhedral hexagonal prisms 0.2 mm long.

Veins:

Carbonate veins up to 0.2 mm thick.

6. Sample 79H2-199.8 m:

Medium grained (1 to 3 mm) biotite (5%) hornblende (20%) quartz diorite. Drill core cut by one thin carbonate filled fracture.

Thin section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (51%):

Subhedral 0.2 to 2.5 mm in diameter grains which are unzoned and slightly flecked with muscovite and epidote. Flat-stage plagioclase determinations yield: $\perp X$, $Z\Lambda(001) = 24^\circ$, $\perp X$, $Y\Lambda(010) = 22^\circ = An_{39}$ (low); $\perp X$, $Z\Lambda(001) = 20^\circ$, $\perp X$, $Y\Lambda(010) = 17^\circ = An_{35}$ (low).

2. Quartz (15%):

Interstitital, anhedral grains about 0.8 mm in diameter which are unaltered and unstrained.

3. Hornblende (20%):

Pleochroic bluish-green to olive green grains up to 4.0 mm long

4. Biotite (5%):

Pleochroic medium to pale brown flakes up to 0.8 mm long partly altered to chlorite.

5. Chlorite (3%):

Pleochroic medium to pale green flakes with anomalous clove brown interference tints, length-fast and spatially associated with biotite and hornblende from which it is forming by alteration.

6. Epidote (5%):

Prisms up to 1.0 mm long which are colourless with a large indeterminate 2V. It is spatially associated with biotite, hornblende and chlorite.

Accessory Minerals:

1. Apatite:

Subhedral grains up to 0.4 mm long spatially associated with hornblende.

2. Opaque Minerals (1%):

Equant grains 0.1 to 0.2 mm in diameter which are spatially associated with mafic minerals and may be part of their alteration assemblage.

7. <u>Sample 79H2 - 227.5 m</u>:

Light grey, porphyritic (white feldspar, minor quartz) rhyodacite (?) This rock is probably related to unit P1 of The Devastator Assemblage.

Thin Section:

The following minerals are present together with a visually estimated mode:

Phenocrysts:

1. Plagioclase (25%):

Subhedral phenocrysts 1 to 2.5 mm long which are completely pseudomorphed by calcite, "kaolinite" and "illite".

2. Quartz (1%):

Rounded phenocrysts up to 1.5 mm in diameter with an altered rim up to 0.1 mm thick completely surrounding the phenocryst of what may have been cristobalite or tridymite.

3. Biotite (1%):

Pseudomorphs up to 2.0 mm long completely pseudomorphed by calcite and muscovite.

Matrix (73%):

0.1 to 0.2 mm grains which are a mixture of quartz, calcite, "kaolinite", "illite", and chlorite.

Accessory Minerals:

1. Apatite:

Euhedral phenocrysts up to 0.2 mm long.

8. <u>Sample 79H2-268.0 m</u>:

Medium-grained (1 to 2 mm) chloritized biotite (13%) quartz diorite gneiss cut by a 5 mm wide vein of carbonate showing open space filling with calcite crystals growing perpendicular to the walls.

Thin section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (41%):

Xenoblastic, untwinned grains 0.1 to 0.2 mm in diameter and 1 to 1.5 mm in diameter twinned grains which are unzoned. The plagioclase is partly altered by epidote and muscovite. Plagioclase compositions determined by flat-stage methods are: $\perp X$, $Z\wedge(001) = 16^{\circ}$, $\perp X$, $Y\wedge(010) = 19^{\circ} = An_{34}$ (low).

2. Quartz (15%):

Anhedral, unstrained, unaltered grains 0.5 mm in diameter.

3. Chlorite (11%):

Present in two forms: (a) as anomalous berlin blue interference tint flakes which are length-slow and medium to pale green in pleochroism. This form is restricted to chlorite + carbonate pseudomorphs after hornblende; and (b) most of the chlorite is medium to pale green pleochroic flakes with anomalous clove brown interference tints and length-fast. This type is spatially associated with biotite.

4. Muscovite (10%):

Flakes up to 0.2 mm long which are an alteration product of plagioclase.

5. Biotite (3%):

Medium to pale brown pleochroic flakes which are up to 0.5 mm long and spatially associated with chlorite.

6. Hornblende (5%):

Prisms up to 1.5 mm long which are completely pseudomorphed by a mixture of carbonate and chlorite.

7. Epidote (5%):

Prisms or granules 0.1 to 0.5 mm long in plagioclase and spatially associated with mafic minerals.

8. Carbonate (10%):

Fine grains as alteration products of plagioclase and hornblende.

Accessory Minerals:

1. Apatite:

Anhedral grains 0.1 mm in diameter.

2. Zircon:

Tetragonal dipyramids 0.1 mm long.

Veins:

Open space filling of carbonate, quartz and chlorite

9. Sample 79H2-347.0 m:

Medium-grained (2 to 4 mm) biotite (10%) hornblende (10%) quartz diorite.

Thin section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (70%):

Subhedral grains 0.5 to 2.0 mm in diameter which are locally flecked with muscovite and epidote. The grains are unzoned and flat-stage plagioclase determination methods yield: $X' \wedge (010) \perp \alpha = An_{30}$ (low); $\perp X$, $Z \wedge (001) = 23^\circ$ and $\perp X$, $Y \wedge (010) = 19^\circ = An_{38}$ (low); $\perp X$, $Z \wedge (001) = 28^\circ$ and $\perp X$, $Y \wedge (010) = 19^\circ = An_{41}$ (low).

2. Hornblende (10%):

Olive green to bluish green pleochroic prisms up to 1.5 mm long.

3. Biotite (10%):

Medium to pale brown pleochroic flakes 0.3 mm long in clots with hornblende prisms.

4. Chlorite (4%):

Medium to plae green pleochroic flakes with clove brown anomalous interference tints. The flakes are length-fast and spatially associated with the mafic minerals from which they form by alteration.

5. Clinozoisite (4%):

Lemon yellow anomalous interference tints in prismatic grains up to 1.0 mm long. It is spatially associated with mafic minerals and rims allanite as fine grains.

6. Muscovite (2%):

Fine flakes, 0.1 mm long, in plagioclase as an alteration product.

Accessory Minerals:

1. Allanite:

A large (4.0 mm long) pleochroic grain in shades of medium to pale brown which is twinned and fringed with clinozoisite.

2. Apatite:

Anhedral grains 0.1 mm spatially associated with mafic minerals.

3. Zircon:

Two tetragonal prisms terminated by tetragonal pyramids.

4. Opaque Minerals:

Equant grains up to 0.4 mm in diameter.

Veins:

Veins up to 0.1 mm thick composed totally of carbonate.

(b) Samples from DDH 79H3:

1. Sample 79H3-52.0 m:

Fine to medium-grained (0.5 to 2.0 mm) biotite (15%) quartz diorite gneiss or paragneiss (uncertain).

Thin section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (52%):

Some twinned grains about 1.0 mm in diameter but most are fine (0.05 mm in diameter) untwinned and unzoned xenoblastic grains. Flat-stage plagioclase composition determinations yield: $\perp X$, $Z \wedge (001) = 17^{\circ}$, $\perp X$, $Y \wedge (010) = 20^{\circ} = An_{34}$ (low); $\perp X$, $Z \wedge (001) = 18^{\circ}$, $\perp X$, $Y \wedge (010) = 21^{\circ} = An_{36}$ (low).

2. Biotite (15%):

Medium chocolate brown to pale brown pleochroic flakes up

0.4 mm long which are preferentially oriented parallel to the foliation.

3. Chlorite (1%):

Medium to pale green pleochroic flakes up to 0.4 mm long with anomalous clove brown interference tints and length-fast. The mineral is present as an alteration product of hornblende and biotite.

4. Hornblende (2%):

Prisms up to 1.0 mm long which are partly pseudomorphed by a mixture of chlorite-montmorillonite and carbonate which leaves less than 0.2% of the hornblende as relicts.

5. Quartz (20%):

Xenoblastic grains 0.1 to 0.5 mm in diameter which are uniaxial positive.

6. Epidote (10%):

Colourless grains 0.2 to 0.5 mm in diameter which have a large $2V_x$.

Accessory Minerals:

1. Allanite:

Pleochroic light to medium brown cores of a few epidote grains.

2. Apatite:

Anhedral grains about 0.1 mm in diameter.

2. <u>Sample 79H3-106.0 m:</u>

Well-layered (2 to 5 cm thick) pyritiferous amphibolite with widely spaced hairline fractures filled with carbonate.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Hornblende (35%):

Prismatic grains up to 2 mm long with blue-green to olive green pleochroism and preferentially oriented to define a lineation.

2. Biotite (17%):

Medium to pale brown flakes which are randomly oriented.

3. Chlorite (2%):

Pale to very pale green pleochroic flakes with anomalous clove brown interference tints. Flakes up to 0.8 mm long are length-fast.

4. Epidote (10%):

Pale yellow-green to colourless equant grains up to 0.5 mm long

5. Plagioclase (31%):

Xenoblastic grains up to 0.5 mm in diameter which are diffusely zoned to more sodic rims. Flat-stage plagioclase determinations yield: $\perp X$, $Z \wedge (001) = 17^\circ$, $\perp X$, $Y \wedge (010) = 13^\circ = An_{31}$ (low).

6. Quartz (3%):

Xenoblastic grains up to 0.4 mm in diameter present in some layers.

Accessory Minerals:

1. Opaque Minerals:

Equant grains 0.05 to 0.5 mm long on edge.

Veins:

There are two sets of veins. Quartz forms the earlier veins up to 1.0 mm thick, and carbonate the later veins up to 0.2 mm thick.

3. Sample 79H3-147.5 m:

Medium to dark grey, medium-grained (2 to 4 mm), layered (2 to 3 cm) streaky amphibolite with 1% pyrite.

Thin section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (38%):

Xenoblastic grains 0.5 to 1.5 mm in diameter which are unzoned and as untwinned diffusely zoned grains up to 0.2 mm in diameter Flat-stage plagioclase composition determinations yield: $\perp X$, $Z \wedge (001) = 29^{\circ}$, $\perp X$, $Y \wedge (010) = 26^{\circ} = An_{52}$ (low).

2. Hornblende (60%):

Pleochroic olive green to blue green to olive brown prisms 0.1 to 2.0 mm long which are preferentially oriented to define a foliation.

3. Biotite (< 1%):

Medium to pale brown pleochroic flakes up to 0.1 mm long.

4. Epidote (½%):

Pale yellow-green pleochroic grains 0.1 to 0.3 mm in diameter in clots.

5. Chlorite (½%):

Medium to pale green pleochroic flakes up to 0.1 mm long with clove brown anomalous interference tints and length-fast.

6. Opaque Minerals (1½%):

Equant opaque grains 0.2 mm in diameter sprinkled throughout.

Vein:

Filled with very fine-grained (0.02 to 0.1 mm) xenoblastic carbonate grains which are untwinned. The veins are both parallel to and crossing the foliation. The veins are up to 0.3 mm thick.

4. Sample 79H3-196.5 m:

Light grey, medium grained (1 to 2 mm) muscovite (20%) gneissic quartz diorite. Thin fractures less than 1 mm thick are filled with carbonate.

Thin section:

The following minerals are present together with a visually estimated mode:

1. Plagioclase (45%):

Anhedral grains heavily altered by muscovite and carbonate. The grains are 1 to 2 mm in diameter and unzoned. Flat-stage plagioclase composoition determinations yield: $\perp X$, $Z\Lambda(001) = 21^{\circ}$, $\perp X$, $Y\Lambda(010) = 15^{\circ}$ = An_{35} (low).

2. Quartz (25%):

Interstitial grains 0.5 mm in diameter which are unaltered and unstrained.

3. Muscovite (20%):

Present as (a) coarse flakes 0.5 to 1.5 mm long and (b) as fine flakes 0.05 to 0.15 mm long in plagioclase grains as an alteration product.

4. Carbonate (10%):

Present as veins and as fine grains in plagioclase where it is an alteration product.

Accessory Minerals:

1. Apatite:

A few subhedral grains 0.1 mm in diameter.

2. Opaque Minerals:

Fine equant grains sprinkled throughout.

Veins:

Veins form up to 5% of the rock and consist of early quartz veins up to 1.0 mm wide cut by carbonate veins.

5. Sample 79H3-211.5 m:

Light grey porphyritic (plagioclase (15%), biotite (2%)) andesite. No fractures or fracture fillings in the hand specimen. The sample may be an intrusion which is part of unit P6i.

Thin Section:

The following minerals are present together with a visually estimated mode:

Phenocrysts:

1. Plagioclase (15%):

Subhedral grains which commonly have partly resorbed rims up to 0.2 mm thick. Some of the phenocrysts are partly replaced by carbonate. Flat-stage plagioclase composition determinations yield: $\perp X$, $Z \wedge (001) = 20^\circ$(rim) and 25°(core), $\perp X$, $Y \wedge (010) = 17^\circ$(rim) and 23°(core) = An_{29} (high) (rim) and An_{34} (high) (core). On a grain which has a partly resorbed rim which is more calcic than the core, fresh core: $\perp X$, $Z \wedge (001) = 24^\circ$, $\perp X$, $Y \wedge (010) = 20^\circ$ = An_{32} (high); and on altered rim: $\perp X$, $Z \wedge (001) = 30^\circ$, $\perp X$, $Y \wedge (010) = 26^\circ$ = An_{37} (high). The corroded rim which is more calcic than the core is characteristic of some of the units of the Meager Volcanic Complex.

2. Biotite (2%):

Dark chocolate brown to medium brown pleochroic flakes up to 1.5 mm long.

3. Hornblende (0.25%):

Pleochroic light to medium brown phenocrysts up to 0.3 mm long.

Matrix (83%):

1. Quartz (3%):

Fine < 0.1 mm diameter grains which are uniaxial positive.

2. Plagioclase:

Matrix plagioclase is present in unaltered euhedral laths which yield a plagioclase composition by the flat-stage carlsbad-albite method of An_{33} (high) and An_{33} (high) based on two sets of $X' \wedge (010) = 23^{\circ}$ and 7°.

3. Biotite:

Fine flakes up to 0.1 mm long.

Accessory Minerals:

1. Apatite:

Euhedral hexagonal prisms up to 0.1 mm long in matrix.

Alteration:

1. Calcite:

Fine grains, untwinned, locally within plagioclase phenocrysts and replacing from 1 to 2% of the rock.

6. Sample 79H3-239.5 m:

Dark grey, massive, medium to coarse grained (2 to 6 mm) hornblendite or possibly amphibolite. Thin fractures (< 1 mm thick) pervade the specimen forming a stockwork of veins composed of gypsum, anhydrite and carbonate ± albite.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Hornblende (61%):

Pleochroic γ = blue-green, β = olive green and α = very pale olive green grains which are stubby prismatic up to 3 mm long.

2. Chlorite (10%):

Randomly oriented pleochroic flakes from very pale green to colourless which have light grey interference tints and are length-fast.

3. Muscovite (0.25%):

A few colourless flakes between hornblende grains.

4. Epidote (0.25%):

A few granular aggregates 0.2 mm in diameter which lies between hornblende grains.

5. Sphene (0.25%):

Xenoblastic to diamond-shaped grains spatially related to hornblende.

Alteration:

1. Anhydrite (2%):

Optical properties are: $2V_z = 40^\circ$, 2 cleavages at 90° with the trace of the optic plane perpendicular to the length of the grains when looking down Z. Extinction is parallel, birefringence is 0.035 assuming the thin section is approximately 0.03 mm thick. The mineral is present as grains up to 0.3 mm in diameter which are interstitial to hornblende grains and form cores of gypsum areas.

2. Gypsum (25%):

Felted masses with refractive indices in the range 1.520 to 1.527 with a birefringence of 0.007 and mixed elongation. It composes all of the area interstitial to hornblende grains and rims anhydrite cores. It is probably present as the alteration of former plagioclase.

3. Carbonate (< 0.25%):

A few untwinned grains within the gypsum alteration.

4. Plagioclase (albite) (0.50%):

Anhedral grains up to 0.4 mm in diameter with polysynthetic twinning and $X' \wedge (010) \perp a = -14^\circ = An_3$ (low)

7. <u>Sample 79H3-251.0 m</u>:

Medium grained (2 mm) hornblende(20%) quartz plagioclase gneiss cut by fractures coated with gypsum.

Thin Section:

The following minerals are present together with a visually estimated mode:

1. Hornblende (20%):

Subhedral, prismatic blue-green to olive green pleochroic grains up to 0.8 mm long

2. Plagioclase (45%):

Subhedral, unzoned grains which are weakly altered by muscovite and epidote. Grains are up to 2.0 mm in diameter. Plagioclase composition determinations on the flat-stage yield by the carlsbad-albite method extinction angles of $X' \Lambda (010) = 17^{o}$ and $29^{o} = An_{53}$ (low), and 28^{o} and $15^{o} = An_{51}$ (low).

3. Quartz (8%):

Interstitial, unaltered grains up to 0.4 mm in diameter.

Accessory minerals:

1. Apatite:

A few subhedral grains up to 0.3 mm long.

Alteration - propylitic:

1. Epidote (20%):

Prismatic pale yellow-green to colourless grains < 0.8 mm long.

2. Chlorite (5%):

Pleochroic medium to pale green flakes which are length-fast and have anomalous clove brown interference tints.

3. Opaque Minerals (2%):

Equant grains up to 0.5 mm in diameter.

Veins (1%):

1. Quartz veins up to 0.3mm thick which are the earliest vein set.

2. Carbonate veins which are hairline thick (up to 0.1mm thick) and cut the quartz veins.

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Petrography and alteration of samples from 79H1, Meager Creek Geothermal area, British Columbia; unpubl. rept. to Nevin Sadlier Brown, Goodbrand Ltd., 14 p.

APPENDIX I:

X-RAY DIFFRACTOGRAMS

(with original copy only)

APPENDIX C-4

Vancouver Petrographics Ltd.

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Report for: Brian Fairbank,
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VANCOUVER, B.C.

Invoice 1937

Samples: 19 samples from Meagre Creek Geothermal Area
(Preliminary Alteration Study)

The samples were grouped into the following rock types (some gradations exist between units, and some samples might fit more than one unit; these gradations are shown by including samples in both groups here, but in the accompanying tables samples are listed in only one category):

1) Coarse Quartz Diorite
   a) biotite
      79ALT-4, -10, -15, -17, -19, -20,(79H2-255.5m),(79ALT-8)
   b) hornblende, minor biotite to major biotite
      79ALT-8, -14, 79H2-255.5m, 79H2-352.5m

2) Coarse Diorite (hornblende with minor biotite)
   79ALT-18, 79H3-256.5m

3) Gneissic Quartz Diorite
   79ALT-1, 79MEA-1, 79MEA-2

4) Quartz Diorite (medium to coarse) with patches, veinlike zones of very fine grained rock with metamorphic textures
   79ALT-16, 79H2-150m, 79H3-83m, 79H3-201m, (79ALT-20, 79H2-255.5m)

Alteration of plagioclase is variable within and between samples to sericite flakes and locally patches, and to scattered patches of epidote. Calcite alteration is local and minor. A few samples contain muscovite porphyroblasts.

Alteration of hornblende and biotite is very variable between samples and within a few samples; alteration is mainly to chlorite and epidote, with minor Ti-oxide, and locally calcite.

The samples are cut by several types of veins, which can be grouped into an earlier epidote-(chlorite) type, probably related in age to the epidote-chlorite alteration of mafic minerals, and a later type composed mainly of calcite with locally minor chlorite.

A slight zonation pattern is recognized around the geothermal zone at the south end of the property. It is marked by a high sericite/epidote ratio in altered plagioclase, and the presence of late calcite veins.

John Payne
John Payne,
January, 1980.

ROCK TYPES

1) Coarse Quartz Diorite

Grain size is mainly coarse to medium, with a massive texture of slightly intergrown subhedral to anhedral grains. Plagioclase, probably andesine in composition is moderately concentrically zoned, with more-calcic cores and more-sodic rims, and a few reversals in the zones in some rocks. Quartz commonly forms coarse patches of moderately to strongly interlocking grains, as well as occurring in finer grained interstitial zones with plagioclase, and in several rocks with microcline. Myrmekitic intergrowths of plagioclase and quartz are present, and are more common where K-feldspar is present in the groundmass. Textures in the finer grained groundmass are mosaic intergrowths suggesting a metamorphic origin.

Samples are divided into two subtypes on their mafic mineral content: some samples contain only biotite, and others contain biotite and hornblende. Magnetite is more common in the hornblende-bearing variety. Mafic minerals are variably altered to chlorite-epidote-Ti oxide, with the latter commonly along cleavage planes in the original mafic mineral.

Sample 10 contains abundant euhedral to subhedral sphene grains up to 2 mm long. It also contains minor calcite associated with patches of coarse quartz. Apatite is locally abundant as grains up to 0.5 mm in size, especially in the hornblende-bearing variety.

2) Diorite

The diorite is similar to the hornblende-bearing quartz diorite but contains more hornblende and only minor quartz.

3) Gneissic Quartz Diorite

These rocks have a predominantly metamorphic texture characterized by mosaic textures and generally fine grain size.Myrmekitic textures are common in the fine grained zones in some samples. Hornblende is commonly poikilitic, or is surrounded by poikilitic biotite with abundnat irregular intergrowths of quartz. Mafic minerals are mainly fresh, suggesting that these rocks did not undergo the main chlorite-epidote (propylitic) alteration which affected the intrusive rocks. Magnetite and apatite are rare, also suggesting that these rocks have a different source than the quartz diorites.

4) Mixed Quartz Diorite with fine grained metamorphic zones

These samples are similar in many respects to the coarse quartz diorite described above, but they contain abundant patches and vein-like zones (in some) of fine to very fine grained rock with two typical textures. The first is similar to that in the gneissic quartz diorite - a mosaic intergrowth of quartz, feldspar, and lesser mafic and epidote grains. The second consists of irregular very poikilitic plagioclase grains containing extremely abundant tiny quartz inclusions. Some samples contain muscovite porphyroblasts up to 1 mm across.

Mineral abundances and alteration intensities are summarised in the following tables (Tables 1 and 2). Vein types are documented in Table 3, and an attempt to quantify the alteration is presented in Table 4. A few conclusions are made relating to the results in these tables.

TABLE 1. Distribution and Alteration of Plagioclase, Hornblende, Biotite, (Epidote)

(ALL VALUES IN PER CENT OF TOTAL ROCK)

Sample No.	Plagioclase total	seric.	epido.	calci.	Hornblende total	chlor.	epido.	Biotite total	chlor.	epido.	Epidote
1) Coarse Quartz Diorite											
a) biotite											
79ALT 4	55-60	5- 7	2- 3					15-17*	8-10	6- 7	**
79ALT 10	45-50	2- 3	3- 4	minor				10-12	5- 7	2- 3	2- 3
79ALT 15	50-55	2- 5	2- 5					10-12	2- 3		5- 7
79ALT 17	55-60	1- 2	3- 5					15-17	minor	minor	0
79ALT 19	45-50	10-15	3- 5		minor			12-15*	6- 8	6- 7	3- 5
79ALT 20	45-50	2- 5	7-10					7-10	3- 5		5- 7
79H2-255.5m	50-55	1- 3			3- 5*	2	2	12-15	8-10	3- 4	1- 2
b) hornblende-biotite											
79ALT 8	60-65	½- 1	2- 3	trace	3- 5*	2	2	10-12	1½-2		1- 2
79ALT 14	50-55	1½-2			5- 7	(fresh)		12-15	6 -8	2- 3	**
79H2-352.5m	55-60	1- 3			12-15	(fresh)					
2) Coarse Diorite (hornblende with minor biotite)											
79ALT 18	60-65	(fresh)			20-25	(fresh)		3- 5	1	minor	0
79ALT 18 - vein		7-10	2- 3	½- 1	*	10-15	8-12	*	2- 3	1- 2	
79H3-256.5m	70-75	0-10			20-25	10-12	7-10 (calcite 1-2)	1*	1		
3) Gneissic Quartz Diorite											
79ALT 1	55-60	0	2- 3 (kaolinite? ½-1)		4- 5	(fresh)		7-10	½		5- 7
79MEA 1	55-60	20-30	0- 5		10-15	(fresh)					5- 7
79MEA1 (vein)	3- 5				2*	2					30-35
79MEA 2 (coarse)	60-65	3-10			3- 5	(fresh)		10-15	1	1	3- 5
(fine)	40-45	0- 2			½	(fresh)		5- 7	(fresh)		2- 3

<u>TABLE 1</u>. (continued)

Sample No.	Plagioclase # total	seric.	epido.	calci.	Hornblende total	chlor.	epido.	Biotite total	chlor.	epido.	Epidote
4) Rocks with medium to coarse quartz diorite cut? by fine grained zones of massive to gneissic quartz diorite, the latter generally more leucocratic than the main rock											
79ALT 16	35-40	0- 5						2- 3	(fresh)		
79H2-150m	30-35	1- 3			17-20	(fresh at one end, gradational to completely altered to chl 10-12, calc 7-8 at other end		3- 5	2- 3		1
79H3-83 m	30-35	1- 3, but up to 10-15 along one edge of section			5- 7	(fresh to 1 chl, 1 epi)		7-10	4- 5	2- 3	5- 7
79H3-201m	25-30	2- 5 (minor kaolin) 3-4 muscovite porphyroblasts						2- 3	minor		20-25

* indicates original mineral is completely altered

** in some samples it is difficult to distinguish epidote which formed by alteration of mafic minerals and epidote patches of unknown parentage; in these epidote is either included with alteration of mafic or listed by itself, depending on which origin appears more probable.

totals do not include plagioclase in fine grained intergrowths with quartz and in some samples with quartz and microcline. (these values are given in Table 2)

TABLE 2. Other minerals and aggregates, generally fresh

Sample No.	Quartz	K-feld.	Musc.	Apat.	Magn.	Opqe.	Sphe.	Fine grained aggregates Qtz,feldspar, some epidote and mafics
1) Coarse Quartz Diorite								
a) biotite								
79ALT 4	20-25	0	0	1	0	minor	0	0
79ALT 10	15-20	5	0	0.3	0	trace	2	10-15
79ALT 15	20-25	0	0	1	0.5	1	minor	2- 3
79ALT 17	20-25	0	0	1	0	minor	minor	0
79ALT 19	20-25	7-10	0	1	0	trace	1½-2	10-15
79ALT 20	20-25	0	0	0.5	0	1	0	17-20
79H2-255.5m	15-20	0	0	1	0	2-3	0	20-25
b) hornblende, minor biotite to major biotite								
79ALT 8	15-20	1	0	trace	minor	1	minor	0
79ALT 14	20-25	0	0	1-2	0.3	0.5	0	0
79H2-352.5m	20-25	0 (1-2% scapolite?)	minor	2	1½-2	1		3- 5
2) Coarse Diorite								
79ALT 18	2- 3	0	0	minor	2½-3	?	0	0
79H3-256.5m	minor	0	minor	1½-2	minor	1-1½	0	0
3) Gneissic Quartz Diorite								
79ALT 1	15-20	0	0	trace	0.2	minor	1-2	0
79MEA 1	25-30	0	0	0	0	1	0	0
79MEA 2 crse	20-30	0	0	0	0	1	minor	0
79MEA 2 fine	40-45	3-5	0	0	0	1	1	0
4) Mixed Quartz Diorite with fine grained metamorphic zones								
79ALT 16	25-30	0	10-15	minor	0	2	0	20-25
79H2-150m	15-20	0	trace	1½-2	0.5	2-2½	0	15-20
79H3-83m	17-20	1-2	0	1	0	minor	0	25-30
79H3-201	15-20	0	3-4	0	0	1-1½	0	25-30

TABLE 3. Vein types and distribution

1) Epidote veinlets, discontinuous

   79ALT-15, 79H2-255.5m, 79ALT-1, 79H2-352.5m, 79ALT-8

2) Epidote-chlorite veinlets, discontinuous

   79ALT-4, 79ALT-20, 79ALT-18, 79H3-83m

3) Quartz-epidote-chlorite

   79MEA-1

4) Calcite (later veins than epidote-bearing veins)

   79ALT-8, 79H3-256.5m (abundant veins, some with minor chlorite), 79ALT-16, 79H2-150m, 79H3-83m, 79H3-201m

Samples containing no significant veins:

79ALT-10, -14, -17, -19, 79MEA-2

Late calcite veins are concentrated mainly near the southern geothermal area (only sample 79ALT-8 is outside this region).

Epidote-bearing veinlets are more widespread, and are related in origin to the epidote-chlorite alteration of mafic minerals which affected much of the region.

Summary of Alteration

The intensities of alteration of plagioclase, hornblende, and biotite are quantified as follows: (The method has a large degree of inherent variability, mainly because the variation in alteration within some thin sections is as great as that throughout the area between thin sections)

1) Plagioclase:

An alteration intensity coefficient is calculated by adding the coefficients of alteration due to sericite (and muscovite), epidote, and calcite as follows; and subtracting 2 from the total.

a) sericite

coefficient of alteration	ratio sericite/original plagioclase (sericite includes muscovite)
1	0 - 3
2	3 - 5
3	5 -10
4	10- 20
5	over 20

b) epidote

coefficient of alteration	ratio epidote/original plagioclase
1	0 - 2
2	2 - 3
3	3 - 5
4	5 -10
5	over 10

c) calcite

calcite is too scattered to quantify; if it is present add one (1 to the total alteration coefficinet

2) Hornblende and Biotite

Alteration is determined for each mafic mineral in terms of the ratio (chlorite + epidote)/(original mafic). In some samples it is difficult to determine what the original mafic mineral was.**

coefficient of alteration	ratio
1	0 - 10
2	10 - 25
3	25 - 45
4	45 - 85
5	85 -100

Based on these assumptions and limits, the following table (Table 4) was constructed.

** The total mafic alteration coefficient was calculated by either adding the values for hornblende and biotite, and subtracting 2, or if one was not present in the original rock, by multiplying the value for the other by 2 and subtracting 2.

TABLE 4. Quantification of Alteration Intensities

Sample No.	Plagioclase ser.	Plagioclase epi.	Plagioclase cal.	Plagioclase overall	Hblde	Biot	Overall Mafic
79ALT 4	4	2		4	-	5	8
79ALT 10	2½	3	1	4½	-	4	6
79ALT 15	3	3		4	-	2	2
79ALT 17	1	4		3	-	1	0
79ALT 19	5	4		7	-	5	8
79ALT 20	3	5		6	-	3½	5
79H2-255.5m	2	1		1	5	5	8
79ALT 8	1	3		2	5	2	5
79ALT 14	1½	1		0½	1	4	3
79H2-352.5m	1½	1		0½	1	-	0
79ALT 18 (rock)	1	1		0	1	2	1
79H3-256.5m	3	1		2	5	5	8
79ALT 1	1	2		1	1	1	0
79MEA 1	5	2		5	1	-	0
79MEA 2 (crse)	3	1		2	1	1	0
(fine)	1	1		0	1	1	0
79ALT 16	5	1		4	-	1	0
79H2-150m	2	1		1	1-5	4	5
79H3-83m	2	1		1	1-2	4	3½
79H3-201m	4	1		3	-	1	0

Cursory examination of these data do not indicate any significant patterns of alteration, except that sericitic alteration of plagioclase is generally stronger than epidote alteration of plagioclase in the vicinity of the southern geothermal zone.This is the same zone which had significantly abundant calcite veins.

APPENDIX D - GEOCHEMISTRY

APPENDIX D-1: GEOTHERMOMETERS

Silica

$$T^oC = \frac{1533.5}{(5.768 - \log SiO_2)} - 273.15$$

- assumes adiabatic and isoenthalpic cooling
- SiO_2 in ppm.

Na-K-Ca

$$T^oC = \frac{1647}{\log (Na/K) + B \log (Ca^{1/2}/Na) + 2.24} - 273.15$$

where $B = 4/3$ for $Ca^{1/2}/Na > 1$ and $t < 100^oC$

$B = 1/3$ for $Ca^{1/2}/Na < 1$ and $t\ 4/3 > 100^oC$

- applicable to neutral waters in environments where travertine deposits do not exist
- Molal ion concentrations.

Na/K

$$T^oC = \frac{855.6}{\log (Na/K) + 0.8573} - 273.15$$

- works well for reservoir temperatures in $150^oC - 200^oC$ range
- all forms of the Na/K geothermometer are very sensitive to re-equilibration of the thermal fluids
- ion concentrations in ppm.

APPENDIX D-1 (cont'd)
References

Fournier, R.O., and Rowe, J.J., 1966, Estimation of Underground Temperatures from the Silica Content of Water from Hot Springs and Wet-Steam Wells, Am. Journal of Sci., Vol. 264, pg. 685-697.

Fourneir, R.O., and Truesdell, 1973, An empirical Na-K-Ca geothermeter for natural waters, Geochimica et Cosmochimica Acta, Vol. 37, pg 1255-1275.

Fournier, R.O. 1979, A Revised Equation for the Na/K Geothermometer, Geothermal Resources Council, TRANSACTIONS, Vol. 3, pg 221-224.

APPENDIX D-2 GEOCHEMICAL DATA FROM M6-79D

Sample	Location	Na^+	K^+	Ca^{2+}	SiO_2	HCO_3^-	SO_4^{2-}	Cl^-	Mg^{2+}	Fe_{total}	Mn^{2+}
1	M6-79D from casing zone 60-68m NSBG	10.1	6.82	209	23.8	883.2	16.1	0.89	41.4	0.1	0.69
2	M6-79D from casing zone 60-68m Waterloo	9.1	6.82	210	-	974.2	-	-	43.1	35.5	0.85
3	M6-79D from casing after completion NSBG	9.0	11	240	52	910	15	0.4	42	-	-

Note: All samples in mg/L.

APPENDIX D-3

Certificate of Analysis

CHEMEX LABS LTD.

212 BROOKSBANK AVE.
NORTH VANCOUVER, B.C.
CANADA V7J 2C1
TELEPHONE: [redacted] 984-0221
AREA CODE: 604
TELEX: 043-52597

• ANALYTICAL CHEMISTS • GEOCHEMISTS • REGISTERED ASSAYERS

CERTIFICATE OF ANALYSIS

CERTIFICATE NO. SP A513
INVOICE NO. 34835
RECEIVED Feb. 1/80
ANALYSED Feb. 12/80

TO: Nevin Sadlier-Brown Goodbrand Ltd.
401 - 134 Abbott St.
Vancouver, B.C.
V6B 2K4
ATTN:

SAMPLE NO. :	Lower Concentration Limit (PPM)	79-H1
Antimony	50	< 25
Arsenic	50	< 25
Barium	5	350
Beryllium	5	< 2
Bismuth	5	< 2
Boron	20	see note #2
Cadmium	20	< 10
Calcium	0.05%	> 100 PPM
Chromium	10	< 5
Cobalt	10	< 5
Copper	1	3
Gallium	5	< 5
Germanium	20	< 10
Indium	50	< 25
Iron	0.05%	2.5 ppm
Lead	5	10
Magnesium	0.02%	25 PPM
Manganese	5	350
Molybdenum	10	< 50
Nickel	5	< 2
Niobium	50	< 25
Silver	1	0.5
Strontium	2	1000
Tellurium	200	< 100
Thorium	200	< 100
Tin	10	< 5
Titanium	5	< 2
Vanadium	20	< 10
Zinc	50	< 25
Zirconium	20	< 10

NOTE:
1. Results are reported in PPB, ug/L, except Ca, Fe & Mg which are reported in PPM, mg/L.
2. Boron content of residue is equivalent to 10 PPB in solution. Due to volatilization of boron during the evaporation to dryness step of the procedure, the actual boron content of the sample solution is probably two to ten times this amount.

SEMI QUANTITATIVE SPECTROGRAPHIC ANALYSES

>5000 ppm	=> 5000 ppm	50 ppm	= 25–100 ppm
5000 ppm	= 2500–10000 ppm	20 ppm	= 10–50 ppm
2000 ppm	= 1000–4000 ppm	10 ppm	= 5–20 ppm
1000 ppm	= 500–2000 ppm	5 ppm	= 2–10 ppm
500 ppm	= 250–1000 ppm	2 ppm	= 1–4 ppm
200 ppm	= 100–400 ppm	1 ppm	= 0.5–2 ppm
100 ppm	= 50–200 ppm	bcl	= below concentration limit

Ranges for Iron, Calcium & Magnesium are reported in %

APPENDIX E - GEOPHYSICS

APPENDIX E - 1

MEAGER CREEK GEOTHERMAL PROJECT

B. C. HYDRO AND POWER AUTHORITY

Report on

D.C. RESISTIVITY SURVEY

in the

UPPER LILLOOET VALLEY

July 1979

by

Greg A. Shore,
PREMIER GEOPHYSICS INC.,
Vancouver, B. C.

September 25, 1979

Work conducted under authority of and in co-operation with: NEVIN SADLIER-BROWN GOODBRAND LTD., Consulting Geologists, Vancouver.

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LIST OF FIGURES

APPENDICES

1.0 Summary and Conclusions

The 1979 resistivity survey program in the upper Lillooet valley has defined a large resistivity anomaly surrounding the single-line anomalous zone discovered in 1978. In addition, four other areas of exploration interest have been identified and appear worthy of further investigation.

2.0 Introduction

In July 1979, Premier Geophysics Inc. of Vancouver, B.C. conducted a resistivity survey of a selected portion of the upper Lillooet valley, in the Meager Creek Geothermal Area 60 kilometres northwest of Pemberton, B.C.

Survey specifications and instructions to proceed were provided by Nevin Sadlier-Brown Goodbrand Ltd., of Vancouver, acting on behalf of the British Columbia Hydro and Power Authority.

2.1 Program Management

The survey program was operated to specifications set forth in an operating agreement between Nevin Sadlier-Brown Goodbrand Ltd. and Premier Geophysics Inc. Greg A. Shore, geophysical consultant to Premier Geophysics, was responsible for the scientific conduct of the field survey, in consultation with the on-site Nevin Sadlier-Brown Goodbrand geophysicist, John Reader. Overall project supervision was provided by Brian D. Fairbank, P. Eng., of Nevin Sadlier-Brown Goodbrand Ltd.

Preparatory cutting and chaining of a survey grid and the establishment of fly camps was undertaken by Nevin Sadlier-Brown Goodbrand Ltd., who also provided support functions during the survey, including the supply of survey assistants, co-ordination of air access and supply acquisition, and maintenance of radio contact with the jobsite.

Post-survey data reduction and analysis, and preparation of this report was done by Greg Shore.

2.2 Objectives

The 1979 resistivity program was designed to provide additional geophysical information about the area surrounding a 1978 resistivity anomaly (Line L, Fig. 4) and adjacent test well L1-78D. (Fairbank et al., 1979), and to expand primary geophysical coverage of the upper Lillooet valley.

3.0 Scope of This Report

This report provides a technical description of the survey method employed in the 1979 program.

Calculated field data are presented in conventional pseudosection form together with an interpretation which represents the author's best estimate, using current analysis methods, of the true geoelectric section beneath each survey line.

The geophysical results are discussed in relation to some known geological features. While the interpretation is complete in terms of available information at the time of report compilation, the understanding of the relationship of the resistivity results to area geology will develop further as geological mapping proceeds and diamond drill test results become available.

4.0 Technical Description of the Survey

4.1 Electrode Configuration

A conventional dipole-dipole electrode array was applied, using a dipole spacing (a) of 300 metres and dipole separations (na) with n = 1 to 4. Additional deep resolution was obtained on portions of all lines by expanding the separation to n = 5 to 9. Effective depth penetration thus available was of the order of 600 to 700 metres. A description of resistivity array theory and application is contained in Appendix C of this report.

4.2 Instrumentation

The survey transmitter was a Phoenix Geophysics 3 kilowatt model IPT-1, providing a symmetrical polarity-reversing square wave output at 0.125 hertz. The receiver was a Hewlett-Packard 7155B strip chart recording microvoltmeter, recording the complete signal waveform and noise for later analysis and digitization. Signal buffering and self-potential compensation was accomplished with a Premier Geophysics PG-1A Differential Compensator. Porous pots with copper sulphate solution electrolyte and a copper core were used as potential electrodes for all measurements.

4.3 Data Processing

The field data record was hand digitized, in some cases with the aid of a mechanical method of filtering out telluric disturbances (Premier, 1979). Apparent resistivities were calculated according to the formula given in Appendix C. Data was plotted in Hallof-type pseudosections. Certain portions of the data were treated by Phoenix Geophysics Ltd. of Toronto, Ontario, using a ridge-regression method of data inversion to determine a best-fit model of layered earth resistivities (Pelton, Hallof, 1978). The data used for inversions are identified on the pseudosection plots, and the results are integrated into the interpreted sections (figures 3, 5, 7, 8). The computer printouts provided by Phoenix Geophysics are reproduced in Appendix D.

5.0 Interpretation

Five anomalous areas are discussed, with continuous reference to Figure 2, followed by a line-by-line examination of data and interpretation.

5.1 Resistivity Anomalies

5.1.1 Anomaly A

Now identified on three parallel lines, Anomaly A occupies an area in excess of 3 km^2, with boundaries open on over half of its perimeter including its entire southern (uphill) flank.

Resistive volcanic flows are identified covering a postulated fracture or fissure zone within the crystalline basement. The zone extends deeper than present survey penetration (700 metres) with indications of a continued decrease in resistivity with depth. A hot, heavily fractured water saturated environment is indicated.

5.1.2 Anomaly B

Anomaly B lies to the west of, and may be associated with, Anomaly A. The low resistivity material at depth appears to be continuous across the two areas, though the overlying resistive rock in Anomaly B is metamorphic and/or crystalline (Fairbank et al, 1979, and Fairbank, pers. comm.).

The anomalous area exceeds 1 km^2. Interpretation in this area is heavily dependent on more detailed geological mapping and possibly drilling results.

5.1.3 Anomaly C

Anomaly C is traced for 1.6 km along line Q, and appears to be a 125 metre thick horizon of water saturated, very porous material. It is overlain by 205 metres of resistive rock, possibly volcanic flows, and underlain by very resistive (4000 ohm-metres) rock, probably the quartz diorite basement. Occurring in an area of known thermal activity, such a sequence of layered resistivities represents a high priority target for further investigation. The sequence and ratios of resistivities are suggestive of possible dry steam structure.

5.1.4 Anomaly D

Anomaly D is a large zone of moderately conductive material extending from near surface to 300 or 400 metres depth. Its significance is not known from the present limited geological understanding of the area. There is some possibility that it may be connected with the northern end of anomaly A, since there is nothing in the limited sampling at the east end of line P to exclude some structural association.

5.1.5 Anomaly E

This anomaly is a marked decrease in resistivity beneath 150 metres of (outcropping) quartz diorite. It occurs in an area which may contain the contact between the quartz monzonite of the Fall Creek Stock and the quartz diorite of the Coast Crystalline Belt. The presence of a fracture or alteration zone at the edge of the quartz monzonite stock could be favourable for geothermal activity.

Anomaly E could be associated with Anomaly A, which remains open off the end of line O in the direction of Anomaly E.

5.2 Survey Line Interpretation

5.2.1 Line N (Figure 3)

Line N is located above the break in slope approximately 800 metres south of the 1978 anomaly on line L (see Figure 2).

Overlying resistive units 185 and 280 metres thick extend from 33W to beyond the limit of survey at 8W, a distance of 2.5 km. These are volcanic flows, identified in test well L1-78D as rhyodacite porphyry.

Beneath the flows is a zone of low resistivity, probably in crystalline basement, which extends to depths greater than present survey penetration of 700 metres. The resistivity appears to decrease with depth, possibly dropping to less than 150 ohm-metres.

The low resistivity derives from a highly fractured or fissured, hot, water saturated environment.

West of 33W, a moderately high resistivity unit at surface is made up of metamorphic and/or crystalline rock (Fairbank et al., 1979, and Fairbank, pers. comm.). No deep data is available from line N in this area, but a deep low observed on line M as it crosses the area confirms continuation of the resistivity anomaly to the west.

5.2.2 Line L, 1978 Survey (Figure 4)

The drilling of test well L1-78D 100 metres east of the anomaly provided an indication of the thickness of the overlying volcanics and confirmed the presence of basement rocks (Fairbank et al., 1979). The thickness (255 metres including 47 metres of overlying sediments) fits reasonably with computer-derived estimates of the thickness of volcanics on line N. The presence of quartz monzonite basement at 262 metres confirms that the anomalous low resistivity is in basement, and lends weight to the interpretation of the line N anomaly also lying in basement rocks. Line L provides both east and west side cutoffs for the anomalous zone, suggesting the possibility of a narrow (1 km wide) structural feature possibly extending out into the valley to the north.

5.2.3 Line O (Figure 5)

Line O passes within 200 metres of line L in the vicinity of the

1978 anomaly and test well L1-78D (Figure 2). As would be expected, the line L anomaly data are confirmed: 1000 ohm-metres overlying 200 ohm-metres, with similar background resistivities to the west. To the east, the Lillooet River defines the limit of survey traverse, leaving the east boundary open. The extended depth information suggests that the eastern boundary may not match that of line L, though no firm interpretation can be made with the limited data and possible interference from the river itself. Again no lower limit to the low resistivity zone is seen.

The overlying resistive unit, assumed to be volcanics, is indicated at 165 metres thick. It is reasonable to suspect that the flows may be somewhat thinner here, and particularly that the depth of volcanic boulder material (suspected of making up over 100 metres of the volcanic layers at line L) would be less.

Background levels west of the anomaly are uniformly lower than those of line L, possibly indicating deeper overlying conductive sediments which will lower apparent resistivity measurements.

5.2.4 Line P (Figure 6)

The east half of line P is strongly influenced by conductive overburden and the parallel Lillooet River. Two features only are of note, besides the general low resistivity appearance of most of the line:

a) west of 55W the line rises up out of the conductive cover and a 500 ohm-metre rock is seen, suggesting that the majority of the line may consist of 500 ohm-metre material, similar to that of western line O, masked by conductive overburden, and,

b) a more resistive unit lies beneath the east half of the line at a depth of 300 to 400 metres, a layering somewhat similar to Anomaly D on line Q, almost opposite on the other side of the river.

5.2.5 Line M (Figure 7)

The north end of line M lies in swamp near the Lillooet River, with the data originating from the last dipole (38N - 41N) clearly indicating near-surface conductive masking. Just 750 metres away from the river, the masking is not readily identifiable, though probably present in a more widespread, uniform effect over the alluvial fan. Between 26N and 36N lies moderate resistivity material, probably the 500 ohm-metre unit described on lines O and P.

From 14N to 26N a resistive unit (1300 ohm-metres) overlies conductive material of about 280 ohm-metres resistivity. This is a good fit with western line N, and provides for continuation of the line N anomaly in the resistivity sense, if not specifically in rock type. The overlying resistive rocks are metamorphic and/or crystalline; consideration of the meaning of the apparent continuation of the line N anomaly (anomaly A) westward under line M must await more detailed mapping in the area, and possibly drill results.

South from 8N are conductive rocks possibly associated with the anomaly. Conductivity is apparently due to intense alteration (and therefore high porosity and water content) and sulphide minerals, the resistivity signature further lowered by the deep-V topography prevalent in the south kilometre of this line. (The topography does not artificially enhance the anomaly from 14N to 26N however. The tendency here would be to lower both the value of the overlying resistive unit and the anomalous low, without disturbing the ratio.)

5.2.6 Line Q (Figures 8 and 9)

Line Q is a step-out line located north of the Lillooet River at the break in slope. Where the cliffs are near, or the slope of the mountain parallels closely, the direction of penetration will be centered about a line perpendicular to the average surface plane. Some additional rock volume will act to reduce the measured apparent resistivity a few percentage points, but the relatively constant nature of the slopes paralleling the line ensures that no terrain induced anomalies are recorded.

The extreme eastern end of the line, from 64W to 75W, lies on mapped quartz diorite which yields a resistivity signature of 2000 to 3000 ohm-metres. Beneath approximately 140 metres of the quartz diorite lies an area of significantly reduced resistivity, suggestive of a zone of alteration, fracturing, high temperature, or a combination of these. Somewhere near this anomaly will be located the contact between the quartz monzonite of the Fall Creek Stock (seen on the east side of Salal Creek) and the quartz diorite of the Coast Crystalline Belt (which overlies this anomaly, at least in part). The presence of a fracture zone or alteration zone at the edge of the stock could be favourable for geothermal activity. The present survey line location and stopping point may be permitting only a diluted sample of a zone lying off the end or to one side of the line.

The quartz diorite signature prevails to the west, being overlain between 80W and 98W by a conductive (100 - 180 ohm-metres) layer up to 300 metres thick. The signature continues to underlie various structures to the western limit of the line.

From 98W to 110W a conductive unit (80 - 200 ohm-metres) dominates to a depth exceeding 400 metres. Quartz diorite (?) basement is identified beneath it, with the depth to interface uncertain. The significance of this zone is unclear.

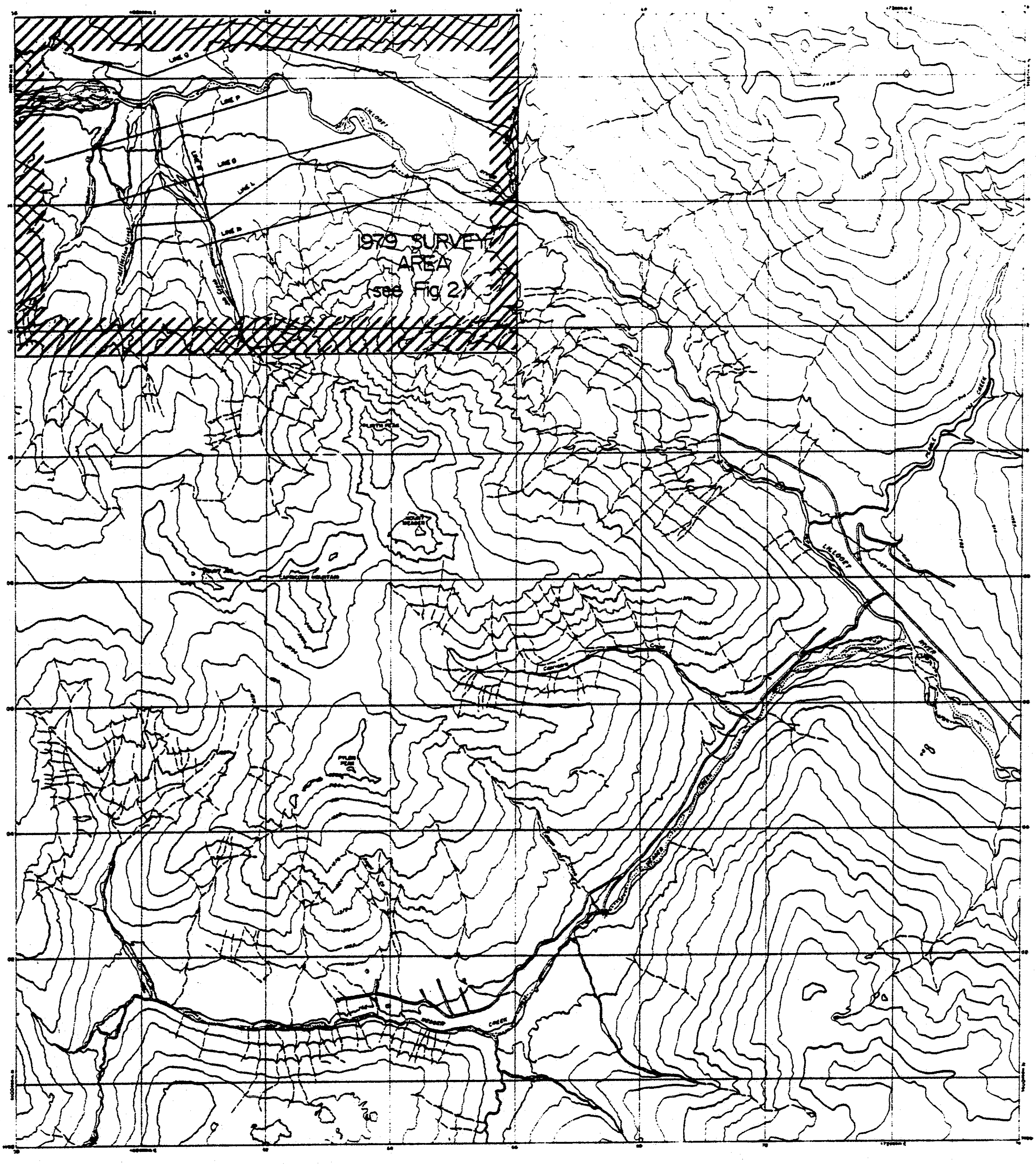
From 110W to 126W a 205 metre thick resistive unit overlies a 125 metre thick horizon estimated at 40 ohm-metres resistivity. A resistive unit (quartz diorite?) underlies the conductive horizon and extends below 500 metres. The extreme ratios of resistivities (1600:40:4000) is suggestive of a dry steam or vapor-dominated geothermal system, with resistive, sealed cap overlying a condensate layer (40 ohm-metres), in turn overlying a hot, dry basement rock. A cold water regime can similarly be presented to explain the data: volcanic flow rocks sealing an extremely conductive, saturated layer of clays and alluvium lying over cold, intact quartz diorite.

Respectfully Submitted,

PREMIER GEOPHYSICS INC.

Greg A. Shore

September 25, 1979



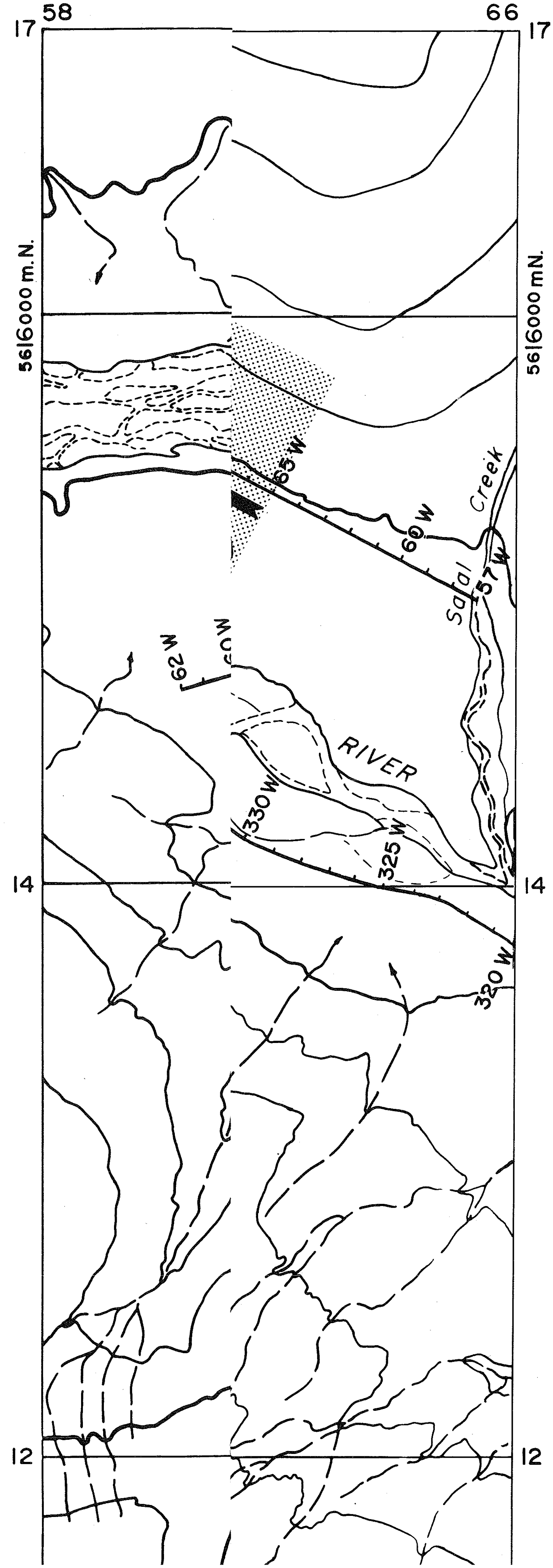
B.C. HYDRO & POWER AUTHORITY
NEVIN SADLIER-BROWN GOODBRAND LTD. CONSULTING GEOLOGISTS
MEAGER CREEK GEOTHERMAL PROJECT

LOCATION OF
D.C. RESISTIVITY SURVEY AREA
UPPER LILLOOET VALLEY

JULY 1979

SURVEY BY PREMIER GEOPHYSICS INC. VANCOUVER B.C.

Figure 1



LEGEND

15W — Resistivity survey line and station

Resistivity anomaly brought to surface

Possible resistivity anomaly

N.B. Line L is a 1978 survey line

A — Anomalous area

←Defined boundary

0 200 400 600 800 1000 1200

METRES

B.C. HYDRO & POWER AUTHORITY

NEVIN SADLIER-BROWN GOODBRAND LTD.
CONSULTING GEOLOGISTS

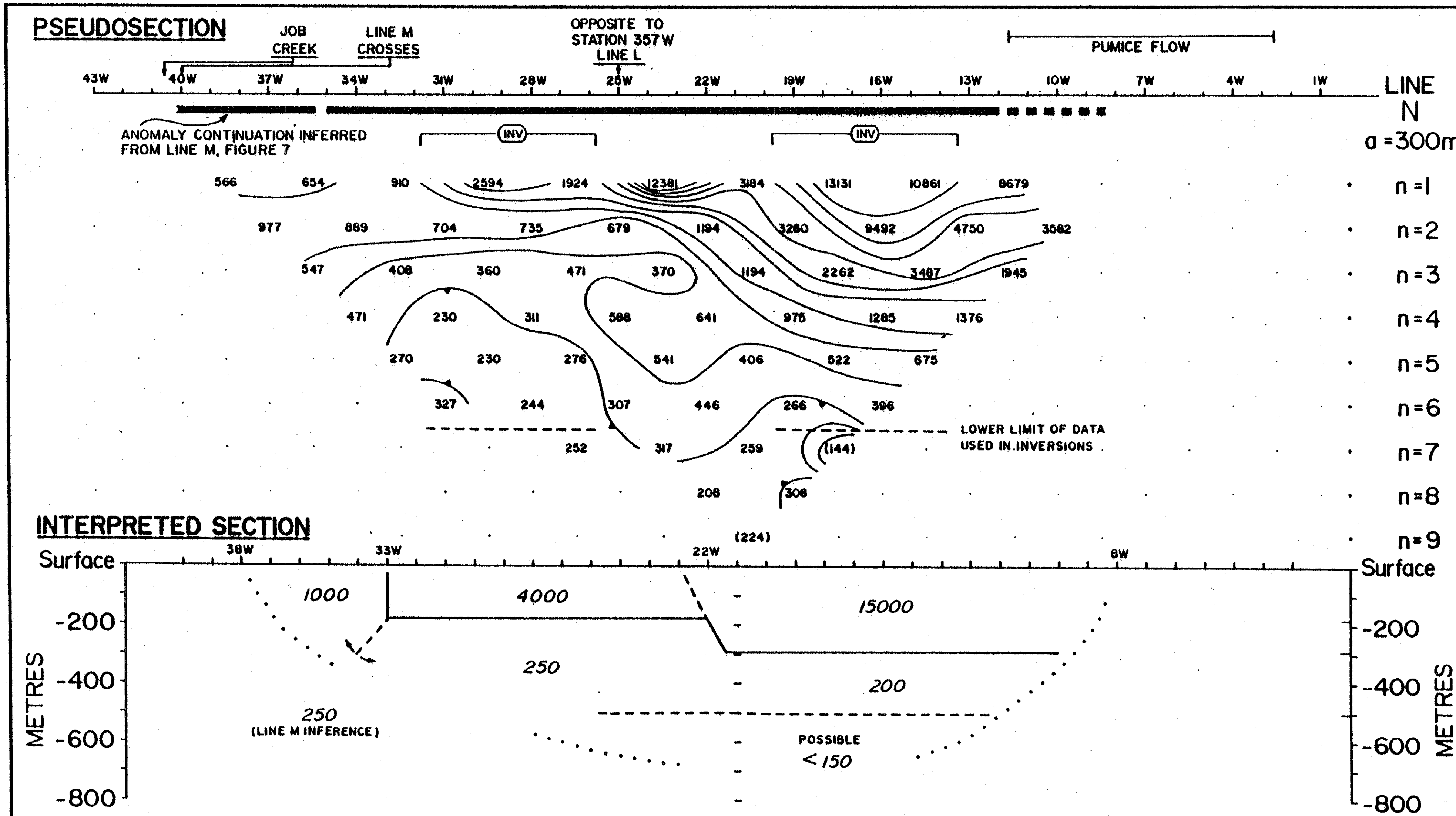
MEAGER CREEK GEOTHERMAL PROJECT

LOCATION OF RESISTIVITY SURVEY LINES AND SUMMARY RESULTS

UPPER LILLOOET VALLEY

JULY 1979

Figure 2



INTERPRETED SECTION

500 INTERPRETED TRUE RESISTIVITY IN OHM-METRES

RESISTIVITY CONTACT

PROBABLE RESISTIVITY CONTACT OR TRANSITION ZONE

LIMIT OF INTERPRETATION

PSEUDOSECTION PLOTTING

$C_1 - C_2$ CURRENT DIPOLE

$P_1 - P_2$ POTENTIAL DIPOLE

a DIPOLE LENGTH

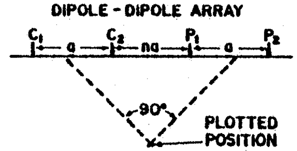
DEFINITE ANOMALY

POSSIBLE ANOMALY

296 APPARENT RESISTIVITY IN OHM-METRES

(INV) SECTION OF DATA TREATED BY INVERSION

CONTOUR INTERVAL IS MODIFIED LOG 1,1.5,2,3,5,7,10



B.C. HYDRO AND POWER AUTHORITY

NEVIN SADLIER-BROWN GOODBRAND LTD., CONSULTING GEOLOGISTS

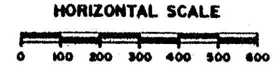
MEAGER CREEK GEOTHERMAL PROJECT

D.C. RESISTIVITY SURVEY

UPPER LILLOOET VALLEY

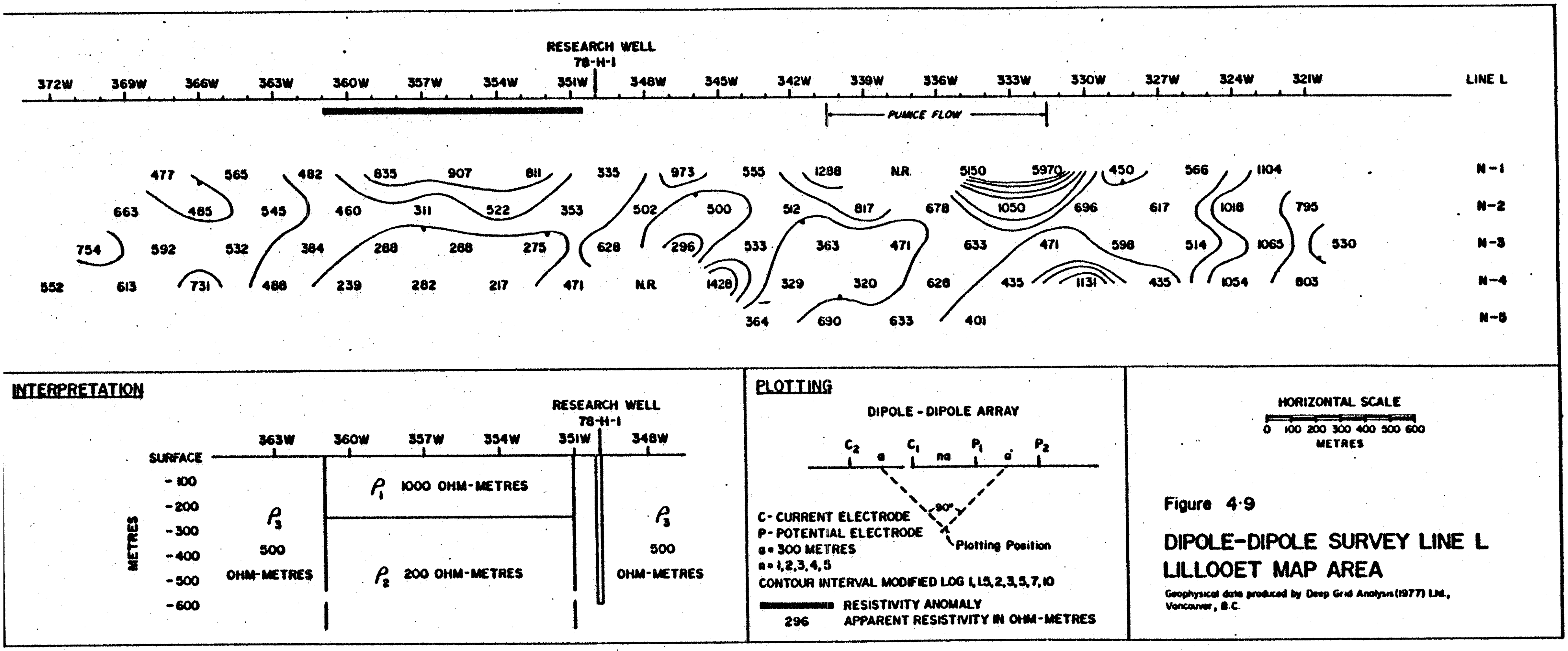
JULY 1979

SURVEY BY PREMIER GEOPHYSICS INC., VANCOUVER, B.C.



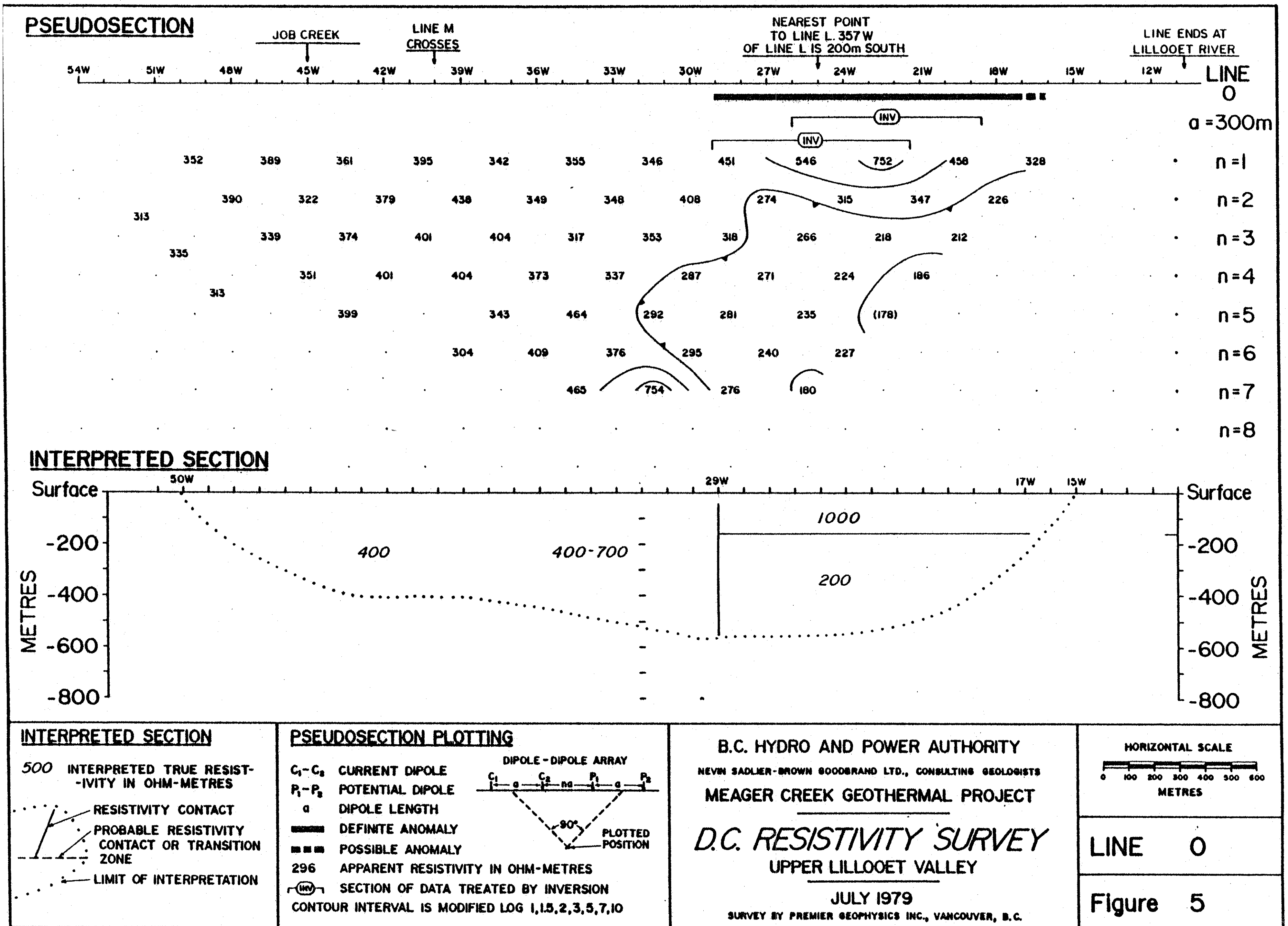
LINE N

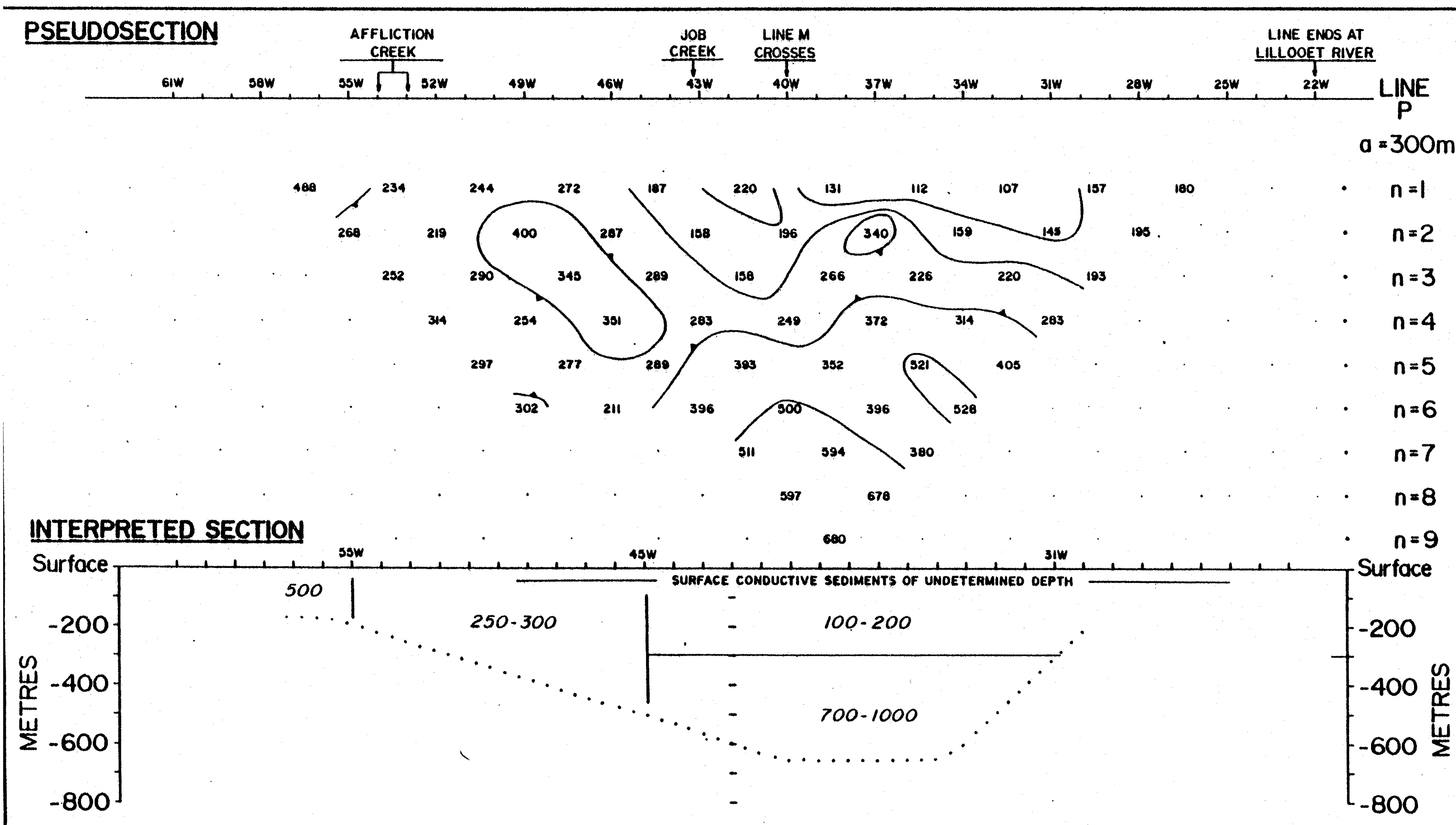
Figure 3



REPRODUCTION OF FIGURE 4.9 FROM "REPORT ON 1978 FIELD WORK, MEAGER CREEK GEOTHERMAL AREA, UPPER LILLOOET RIVER, BRITISH COLUMBIA." (FAIRBANK ET AL., 1979)

Figure 4


PSEUDOSECTION
JOB CREEK
LINE M CROSSES
NEAREST POINT TO LINE L 357 W OF LINE L IS 200m SOUTH
LINE ENDS AT LILLOOET RIVER
54W 51W 48W 45W 42W 39W 36W 33W 30W 27W 24W 21W 18W 15W 12W
LINE 0
a = 300m
INV
n = 1: 352 389 361 395 342 355 346 451 546 752 458 328
n = 2: 313 390 322 379 438 349 348 408 274 315 347 226
n = 3: 335 339 374 401 404 317 353 318 266 218 212
n = 4: 313 351 401 404 373 337 287 271 224 186
n = 5: 399 343 464 292 281 235 (178)
n = 6: 304 409 376 295 240 227
n = 7: 465 754 276 180
n = 8
INTERPRETED SECTION
Surface
50W 29W 17W 15W
-200 -400 -600 -800
METRES
1000
400
400-700
200
INTERPRETED SECTION
500 INTERPRETED TRUE RESISTIVITY IN OHM-METRES
RESISTIVITY CONTACT
PROBABLE RESISTIVITY CONTACT OR TRANSITION ZONE
LIMIT OF INTERPRETATION
PSEUDOSECTION PLOTTING
C1-C2 CURRENT DIPOLE
P1-P2 POTENTIAL DIPOLE
a DIPOLE LENGTH
DEFINITE ANOMALY
POSSIBLE ANOMALY
296 APPARENT RESISTIVITY IN OHM-METRES
INV SECTION OF DATA TREATED BY INVERSION
CONTOUR INTERVAL IS MODIFIED LOG 1,1.5,2,3,5,7,10
DIPOLE - DIPOLE ARRAY
C1 a C2 na P1 a P2
90°
PLOTTED POSITION
B.C. HYDRO AND POWER AUTHORITY
NEVIN SADLIER-BROWN GOODBRAND LTD., CONSULTING GEOLOGISTS
MEAGER CREEK GEOTHERMAL PROJECT
D.C. RESISTIVITY SURVEY
UPPER LILLOOET VALLEY
JULY 1979
SURVEY BY PREMIER GEOPHYSICS INC., VANCOUVER, B.C.
HORIZONTAL SCALE
0 100 200 300 400 500 600
METRES
LINE 0
Figure 5



INTERPRETED SECTION

500 INTERPRETED TRUE RESISTIVITY IN OHM-METRES

RESISTIVITY CONTACT

PROBABLE RESISTIVITY CONTACT OR TRANSITION ZONE

LIMIT OF INTERPRETATION

PSEUDOSECTION PLOTTING

DIPOLE - DIPOLE ARRAY

$C_1 - C_2$ CURRENT DIPOLE

$P_1 - P_2$ POTENTIAL DIPOLE

a DIPOLE LENGTH

DEFINITE ANOMALY

POSSIBLE ANOMALY

296 APPARENT RESISTIVITY IN OHM-METRES

(INV) SECTION OF DATA TREATED BY INVERSION

CONTOUR INTERVAL IS MODIFIED LOG 1,1.5,2,3,5,7,10

PLOTTED POSITION

B.C. HYDRO AND POWER AUTHORITY

NEVIN SADLIER-BROWN GOODBRAND LTD., CONSULTING GEOLOGISTS

MEAGER CREEK GEOTHERMAL PROJECT

D.C. RESISTIVITY SURVEY

UPPER LILLOOET VALLEY

JULY 1979

SURVEY BY PREMIER GEOPHYSICS INC., VANCOUVER, B.C.

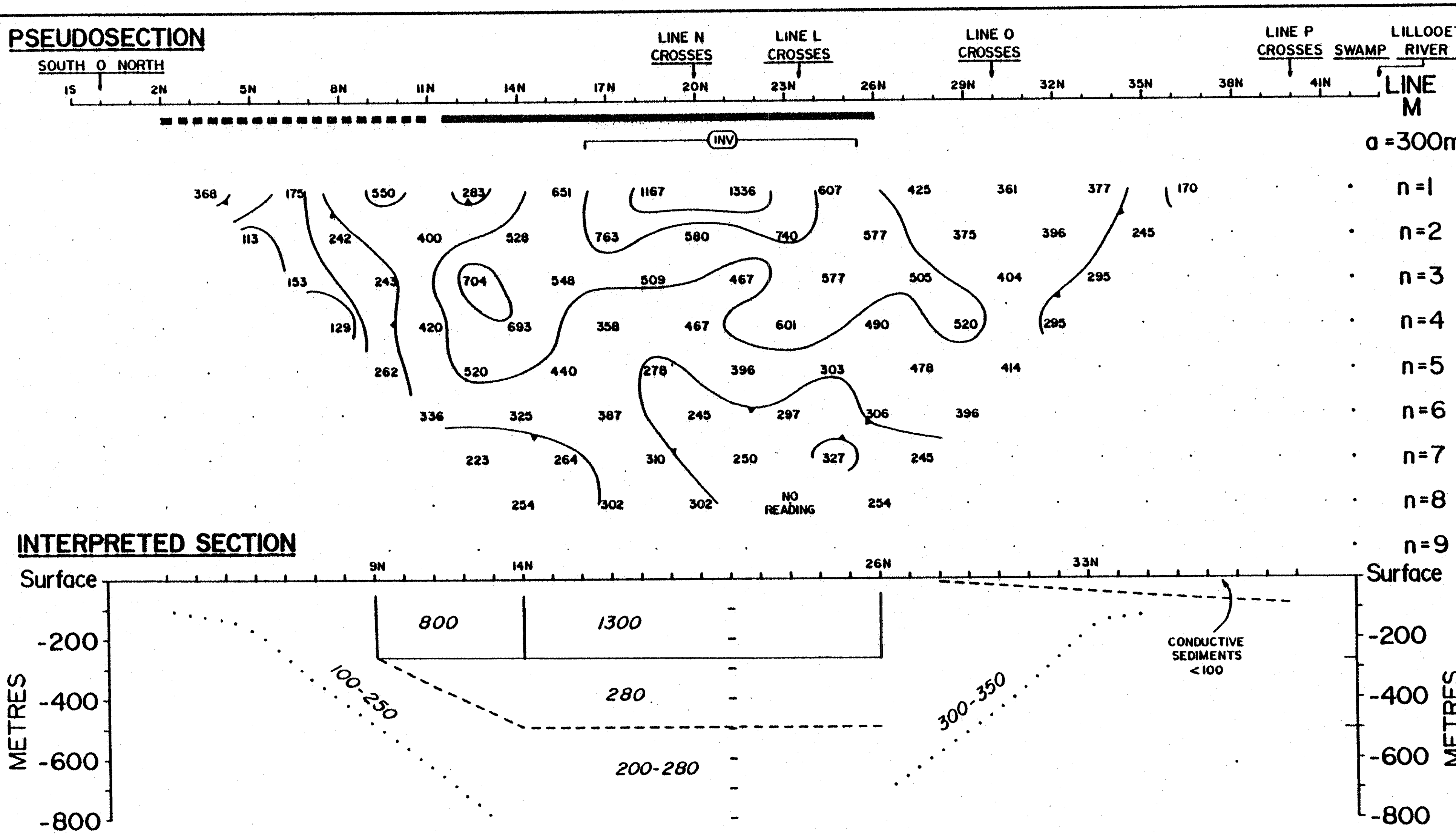
HORIZONTAL SCALE

0 100 200 300 400 500 600

METRES

LINE P

Figure 6



INTERPRETED SECTION

500 INTERPRETED TRUE RESISTIVITY IN OHM-METRES

RESISTIVITY CONTACT

PROBABLE RESISTIVITY CONTACT OR TRANSITION ZONE

LIMIT OF INTERPRETATION

PSEUDOSECTION PLOTTING

DIPOLE - DIPOLE ARRAY

C_1 C_2 P_1 P_2 a na a 90° PLOTTED POSITION

$C_1 - C_2$ CURRENT DIPOLE

$P_1 - P_2$ POTENTIAL DIPOLE

a DIPOLE LENGTH

DEFINITE ANOMALY

POSSIBLE ANOMALY

296 APPARENT RESISTIVITY IN OHM-METRES

(INV) SECTION OF DATA TREATED BY INVERSION

CONTOUR INTERVAL IS MODIFIED LOG 1,1.5,2,3,5,7,10

B.C. HYDRO AND POWER AUTHORITY

NEVIN SADLIER-BROWN GOODBRAND LTD., CONSULTING GEOLOGISTS

MEAGER CREEK GEOTHERMAL PROJECT

D.C. RESISTIVITY SURVEY

UPPER LILLOOET VALLEY

JULY 1979

SURVEY BY PREMIER GEOPHYSICS INC., VANCOUVER, B.C.

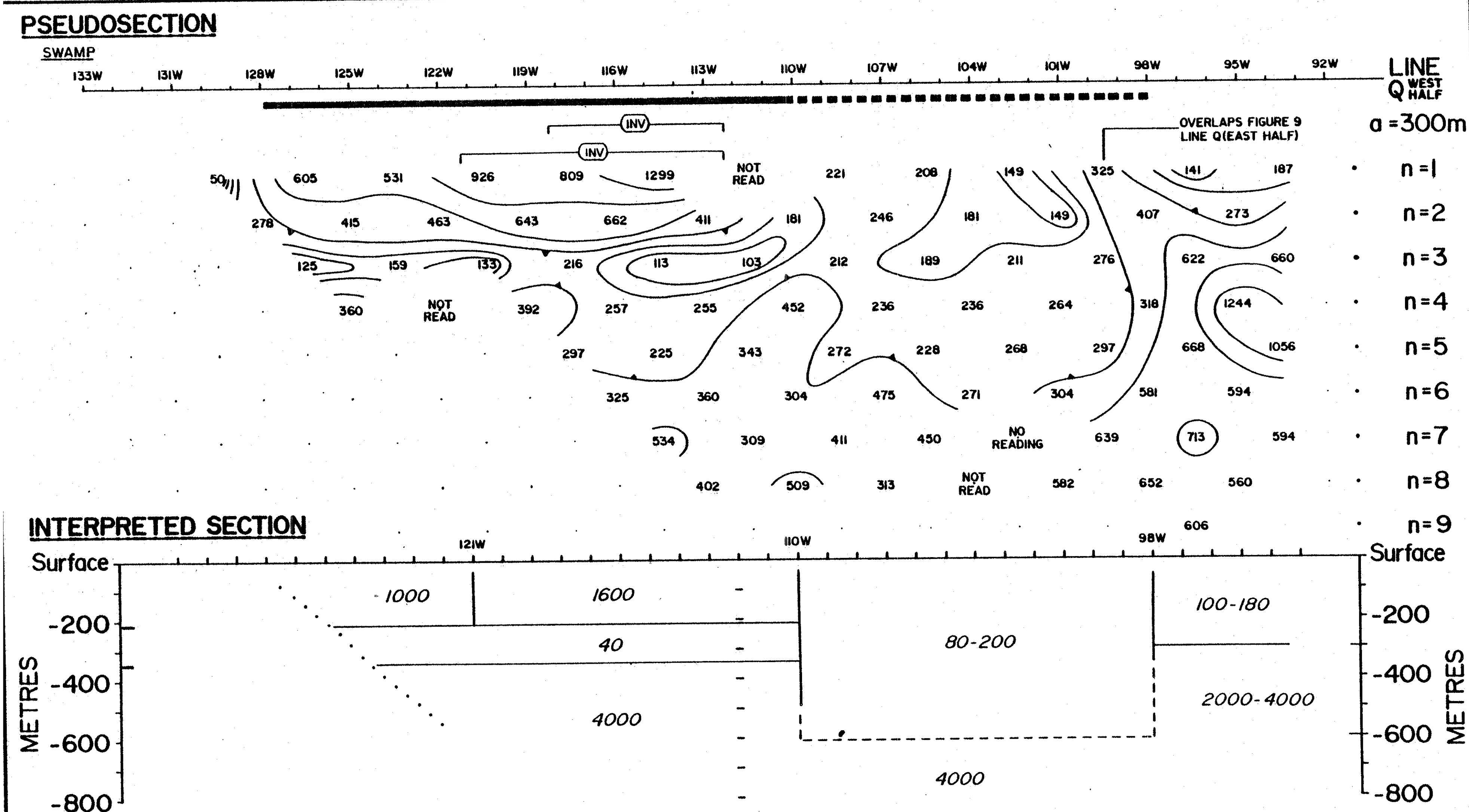
HORIZONTAL SCALE

0 100 200 300 400 500 600

METRES

LINE M

Figure 7



INTERPRETED SECTION

500 INTERPRETED TRUE RESISTIVITY IN OHM-METRES

RESISTIVITY CONTACT

PROBABLE RESISTIVITY CONTACT OR TRANSITION ZONE

LIMIT OF INTERPRETATION

PSEUDOSECTION PLOTTING

DIPOLE - DIPOLE ARRAY

C_1-C_2 CURRENT DIPOLE

P_1-P_2 POTENTIAL DIPOLE

a DIPOLE LENGTH

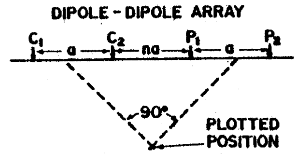
DEFINITE ANOMALY

POSSIBLE ANOMALY

296 APPARENT RESISTIVITY IN OHM-METRES

(INV) SECTION OF DATA TREATED BY INVERSION

CONTOUR INTERVAL IS MODIFIED LOG 1,1.5,2,3,5,7,10



B.C. HYDRO AND POWER AUTHORITY

NEVIN SADLIER-BROWN GOODBRAND LTD., CONSULTING GEOLOGISTS

MEAGER CREEK GEOTHERMAL PROJECT

D.C. RESISTIVITY SURVEY

UPPER LILLOOET VALLEY

JULY 1979

SURVEY BY PREMIER GEOPHYSICS INC., VANCOUVER, B.C.

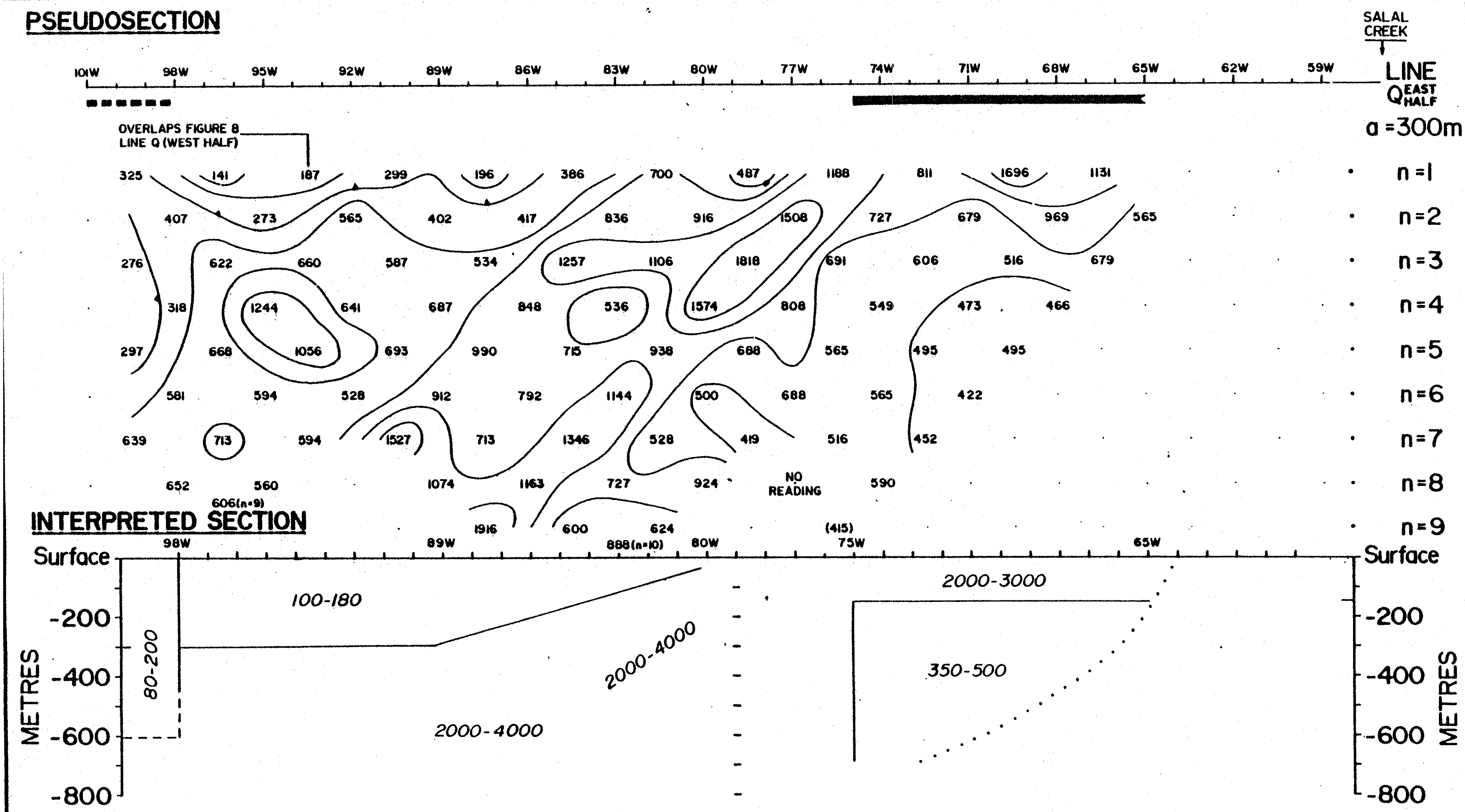
HORIZONTAL SCALE

0 100 200 300 400 500 600

METRES

LINE Q WEST HALF

Figure 8



INTERPRETED SECTION

500 INTERPRETED TRUE RESISTIVITY IN OHM-METRES

RESISTIVITY CONTACT

PROBABLE RESISTIVITY CONTACT OR TRANSITION ZONE

LIMIT OF INTERPRETATION

PSEUDOSECTION PLOTTING

C_1–C_2 CURRENT DIPOLE

P_1–P_2 POTENTIAL DIPOLE

a DIPOLE LENGTH

DEFINITE ANOMALY

POSSIBLE ANOMALY

296 APPARENT RESISTIVITY IN OHM-METRES

(INV) SECTION OF DATA TREATED BY INVERSION

CONTOUR INTERVAL IS MODIFIED LOG 1,1.5,2,3,5,7,10

DIPOLE - DIPOLE ARRAY

C_1 a C_2 na P_1 a P_2 90° PLOTTED POSITION

B.C. HYDRO AND POWER AUTHORITY

NEVIN SADLIER-BROWN GOODBRAND LTD., CONSULTING GEOLOGISTS

MEAGER CREEK GEOTHERMAL PROJECT

D.C. RESISTIVITY SURVEY

UPPER LILLOOET VALLEY

JULY 1979

SURVEY BY PREMIER GEOPHYSICS INC., VANCOUVER, B.C.

HORIZONTAL SCALE

0 100 200 300 400 500 600

METRES

LINE Q EAST HALF

Figure 9

APPENDIX A: SELF-POTENTIAL SURVEY

Summary: A self-potential (SP) anomaly of over 3000 millivolts peak lies partially defined over a portion of 1979 resistivity anomaly A, near drill hole L1-78D. The anomaly is insufficiently mapped to allow detailed interpretation beyond the observation that its magnitude and gradient are approached in the current literature only by the SP anomalies mapped by Zablocki (1975) over collapse craters at Kilauea, Hawaii.

Background: For technical background the reader is referred to Appendix A of the Report on 1976 Geothermal Investigation at Meager Creek, submitted by Nevin Sadlier-Brown Goodbrand Ltd. to the B.C. Hydro and Power Authority. Appendix A is a report describing various mechanisms responsible for self-potential anomalies, and presents results of self-potential surveys in the Lillooet River valley.

The first SP measurements in the area were made in 1975, coincident with a resistivity survey on the south side of the Meager Mountain complex, and reported in the Nevin Sadlier-Brown Goodbrand progress report for that year. The loose correlation of SP results with conductive areas in that survey led to the organization of extensive SP traverses along the Lillooet River valley in 1976, and the principal technical report on SP as mentioned above.

In the 1976 surveys, several distinct SP anomalies of 200 to 300 millivolt (mV) magnitude were located on the south side of the river, between Salal and Pebble Creeks, some spatially associated with resistivity anomalies. These and the large 1000 mV dipolar anomaly mapped between Salal and Meager

Creeks result from a single traverse line (line A) and are of conventional magnitude. Because the values derive from a single traverse across a potential field, the data indicate spot levels on the field and contain peak-value and gradient components that range from full maximum, in the case of chance traversing of the existing anomaly peak, to a small fraction of a possible peak which may exist somewhere to the side of the single traverse.

Survey traverses further west, in the broad valley floor upstream from Salal Creek, were less successful, providing very flat data which did not appear to be normal background values. It was concluded that the deep, saturated overburden and particularly the impermeable varved clay horizons effectively suppressed, dissipated or otherwise masked any normal background or anomalous ion concentrations originating from buried sources.

In 1978, a rapid-reconnaissance dipole-dipole resistivity survey line was placed along the south edge of this same deep overburden area, at or near the break in slope. Here, the instrument operator noticed steep SP gradients in the vicinity of the resistivity anomaly A (Figure A-1), but did not record their values .

In 1979, Shore used non-polarizing copper-copper sulphate porous pot electrodes for the measurement dipole of the resistivity array, specifically in order to be able to observe and record SP gradients as part of the resistivity measurement procedure. Observation and recording was done on lines M, N, and part of O, but was discontinued on lines P and Q in order to speed up survey progress. The 1979 results are reported here.

Survey results, 1979: SP data has been extracted from the resistivity record as gradient values, algebraically added in the direction of the survey progress, and plotted on Figure A-1 as potential field data.

The portions of lines M and O which lie in the deep overburden yield the flat response typical of the 1976 traverses in that area. The overburden influences proposed in 1976 (see background, above) retain their favour in this 1979 review.

Much of southern line M lies on or near bedrock. Line N lies on a different type of overburden than the valley lines: the cover on line N is shallower, better drained, and probably devoid of varved clay layers.

Readings on southern line M and western line N are flat.

Between 20W and 30W on line N SP values are large and gradients steep by world standards, and yet represent only a fraction of the size of response immediately to the east.

In the triangular area defined with vertices at drillsite L1-78D. and at 7W and 20W on line N, the SP gradient is almost 3000 mV/km, and the peak value of 3000 mV is thought to be the largest SP value ever recorded,

The peak magnitude and the voltage gradients measured here are surprising. The field data, crude and spatially incomplete as they are, remain a reliable indicator, due to the initial modifications to the resistivity survey equipment, particularly electrodes. Dedicated SP survey techniques are substantially different from those necessarily employed in "free-riding" on the back of the resistivity survey, but would be expected to confirm the reported data, while providing the closer spacing curve resolution, and the additional parallel and perpendicular traverses required to adequately define the two dimensions of the potential field.

While other SP results in the Meager area fit the general class of reported magnitudes in geothermal areas, the 1979 results are approached in magnitude and gradient only by those reported over collapse craters at Kilauea, Hawaii by Zablocki (1975). Zablocki suggests as a source mechanism streaming potentials from vigorous fluid convection in the fractured collapse materials. The similarity in magnitude and gradient between the Hawaii and the Meager observations leads to speculation that the Meager response may be related to convective circulation in collapse debris in the vent which is presumed to lie in the valley area somewhere.

Completion of detailed SP coverage of the area around the 1979 anomaly would be required to permit evaluation of probable source mechanism(s) and location(s).

It is also pointed out that completion of SP coverage on the north side of the Lillooet River could assist in correlation of resistivity anomalies A and B with northern anomalies C, D, and E, if corresponding SP responses could be detected.

Reference: Zablocki, C.J., 1975, Mapping thermal anomalies on an active volcano by the self-potential method, Kilauea, Hawaii: proceedings, Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, May, 1975.

APPENDIX B

Resistivity Measurement Theory

Measurements of the earth's electrical properties are routinely used to gain insight into the physical makeup of what lies below the surface. In geothermal exploration, the leading approach is "resistivity", an active survey method in which the electrical resistivity characteristics of a selected region are studied. Quantitative estimates of the resistivity value are derived for specific volumes of the subsurface.

Electrical conductivity in rocks (with the exception of metallic or carbonaceous rocks) is principally due to ionic conduction in water-filled, connected pore space. This pore space may be an inherent characteristic of the rock, as in a sandstone, or may derive from interconnected fractures in an otherwise non-porous rock such as the granite basement of the Meager Mountain area.

The resistivity anomaly permitted by the increased fluid communication within a porous or permeable zone may be enhanced in a thermal environment by two factors

a) elevated fluid temperatures
b) dissolved solids, which are characteristically high in geothermal waters.

In the predominantly water-saturated Meager Mountain environment, variation of observed resistivity within a single non-metallic non-carbonaceous rock unit (such as the granitic basement) is interpreted as a function of the degree of fracturing of the rock, with possible contribution from elevated fluid temperatures and to a lesser extent, elevated fluid salinity.

APPENDIX C

Dipole-Dipole Array Theory

Dipole-dipole array surveys are used at Meager Creek when terrain and penetration requirements permit. Dipole-dipole is a standard reconnaissance array, with good vertical resolution, good definition of lateral resistivity changes, and proven operating logistics. It is used in the Meager area along valley bottoms where long, straight survey lines can be laid out. Comparative performance characteristics of the pole-pole and dipole-dipole resistivity arrays have been reviewed previously by Shore (1978). A drawing of a dipole-dipole array is included in Figure 3 - 9. Current is passed into the ground through two current electrodes (current dipole) and the resultant electrical potential measured across two potential electrodes (potential dipole).

The formula for calculation of apparent resistivity is:

$$R(A) = \pi a(n)(n+1)(n+2)Vp/Ig$$

where R(A) = apparent resistivity in ohm metres

a = length in metres of each survey dipole

n = integer multiple of distance "a", defining separation distance between the two survey dipoles

Vp = measured primary voltage across potential dipole, in volts

Ig = current in amperes passed through current dipole

APPENDIX D: Computer Inversion Study Printouts

Line M

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Thk1
0	1.E-01	.00704	1500.0	300.0	250.0
1	1.E-01	.00643	1397.6	284.5	254.0
2	1.E-03	.00633	1324.2	279.7	263.6

Pct Std Deviations 20.6 8.3 13.8

Correlation Matrix

1.0000		
.4676	1.0000	
-.3286	-.7074	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	1167.0	1191.5	-2.1	1
2	1	1336.0	1191.5	10.8	1
3	2	763.0	754.9	1.1	1
4	2	580.0	754.9	-30.1	1
5	2	740.0	754.9	-2.0	1
6	3	509.0	497.9	2.2	1
7	3	467.0	497.9	-6.6	1
8	4	358.0	386.3	-7.9	1
9	4	467.0	386.3	17.3	1
10	4	601.0	386.3	35.7	1
11	5	278.0	339.9	-22.3	1
12	5	396.0	339.9	14.2	1
13	6	387.0	319.1	17.6	1
14	6	245.0	319.1	-30.2	1
15	6	297.0	319.1	-7.4	1
16	7	310.0	308.5	.5	1
17	7	250.0	308.5	-23.4	1
18	8	302.0	302.5	-.2	1
19	8	302.0	302.5	-.2	1

Line N, # 1

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Thk1
0	1.E-01	.01853	5000.0	250.0	200.0
1	1.E-01	.00532	4172.0	249.9	183.0
2	1.E-03	.00515	3893.1	245.5	184.5
3	1.E-05	.00515	3892.3	245.4	184.6

Pct Std Deviations 24.9 8.1 8.9

Correlation Matrix

1.0000		
.4079	1.0000	
-.8704	-.5866	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	2594.0	2199.7	15.2	1
2	1	1924.0	2199.7	-14.3	1
3	2	704.0	757.5	-7.6	1
4	2	735.0	757.5	-3.1	1
5	3	360.0	372.3	-3.4	1
6	3	471.0	372.3	21.0	1
7	4	230.0	289.3	-25.8	1
8	4	311.0	289.3	7.0	1
9	5	230.0	268.7	-16.8	1
10	5	276.0	268.7	2.7	1
11	6	327.0	261.2	20.1	1
12	6	244.0	261.2	-7.1	1

Line N, # 2

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Thk1
0	1.E-01	.01092	13278.8	233.3	290.1
1	1.E-01	.00939	14634.6	217.2	290.4
2	1.E-03	.00934	14869.7	209.0	290.3

Pct Std Deviations 18.5 32.0 6.0

Correlation Matrix

1.0000		
.4263	1.0000	
-.8167	-.7328	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	13131.0	12661.7	3.6	1
2	1	10861.0	12661.7	-16.6	1
3	2	3280.0	6907.3	-110.6	0
4	2	9492.0	6907.3	27.2	1
5	3	2262.0	2953.2	-30.6	1
6	3	3487.0	2953.2	15.3	1
7	4	975.0	1198.9	-23.0	1
8	4	1285.0	1198.9	6.7	1
9	5	522.0	555.9	-6.5	1
10	5	675.0	555.9	17.6	1
11	6	266.0	342.0	-28.6	1
12	6	396.0	342.0	13.6	1

Line O, # 1

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Thk1
0	1.E-01	.00385	1000.0	100.0	200.0
1	1.E-01	.00717	848.4	207.6	191.3
2	1.E-03	.00612	945.2	224.3	154.7
3	1.E-05	.00602	1133.6	224.4	141.3
4	1.E-07	.00601	1176.6	224.6	140.0

Pct Std Deviations 75.7 7.1 32.3

Correlation Matrix

1.0000		
.5898	1.0000	
-.9550	-.6794	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	451.0	560.6	-24.3	1
2	1	546.0	560.6	-2.7	1
3	1	752.0	560.6	25.5	1
4	2	274.0	303.7	-10.8	1
5	2	315.0	303.7	3.6	1
6	3	318.0	252.8	20.5	1
7	3	266.0	252.8	5.0	1
8	3	210.0	252.8	-15.9	1
9	4	271.0	239.5	11.6	1
10	4	224.0	239.5	-6.9	1
11	5	281.0	234.2	16.7	1
12	5	235.0	234.2	.3	1
13	5	178.0	234.2	-31.6	1
14	6	240.0	231.4	3.6	1
15	6	227.0	231.4	-2.8	1
16	7	276.0	229.8	16.7	1
17	7	180.0	229.8	-27.7	1

Line O, # 2

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Thk1
0	1.E-01	.01013	1000.0	200.0	200.0
1	1.E-01	.00433	895.6	189.3	180.4
2	1.E-03	.00429	851.6	186.2	184.0

Pct Std Deviations 28.6 8.1 10.4

Correlation Matrix

1.0000		
.5794	1.0000	
-.9813	-.7402	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	546.0	589.6	-8.0	1
2	1	752.0	589.6	21.6	1
3	1	450.0	589.6	-28.7	1
4	2	315.0	322.0	-2.2	1
5	2	347.0	322.0	7.2	1
6	3	266.0	238.0	10.5	1
7	3	218.0	238.0	-9.2	1
8	3	212.0	238.0	-12.3	1
9	4	224.0	212.9	5.0	1
10	4	186.0	212.9	-14.5	1
11	5	235.0	203.6	13.4	1
12	5	178.0	203.6	-14.4	1
13	6	227.0	199.2	12.3	1
14	7	180.0	196.7	-9.3	1

Line Q, # 1

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Rho3	Thk1	Thk2
0	1.E-01	.01634	1500.0	30.0	1000.0	200.0	100.0
1	1.E-01	.00639	1608.8	33.1	1038.4	204.7	90.6
2	1.E-03	.00626	1665.0	31.7	1750.0	203.9	94.8
3	1.E-05	.00608	1650.4	36.5	3022.2	205.1	111.1
4	1.E-05	.00604	1653.3	42.6	3776.1	204.7	128.2

Pct Std Deviations 45.7 99999.9 59829.1 99999.9 99999.9

Correlation Matrix

1.0000				
.6969	1.0000			
.2560	.6455	1.0000		
-.7088	-.9990	-.6380	1.0000	
.6969	1.0000	.6456	-.9998	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	809.0	1031.4	-21.6	1
2	1	1299.0	1031.4	25.9	1
3	2	662.0	394.9	67.6	0
4	2	411.0	394.9	4.1	1
5	3	216.0	234.2	-7.8	1
6	3	113.0	234.2	-51.8	0
7	4	257.0	237.5	8.2	1
8	4	255.0	237.5	7.4	1
9	5	297.0	275.6	7.8	1
10	5	225.0	275.6	-18.3	1
11	6	325.0	318.9	1.9	1
12	6	360.0	318.9	12.9	1
13	7	534.0	362.3	47.4	0
14	8	402.0	405.1	-.8	1

Line Q, #2

B.C. HYDRO AND POWER AUTHORITY JULY 1979

Electrode Interval= 300

Iter	Lambda	Rchsq	Rho1	Rho2	Rho3	Thk1	Thk2
0	1.E-01	.00761	1800.0	30.0	4000.0	200.0	100.0
1	1.E-01	.00546	1665.5	31.5	4000.1	202.2	95.3
2	1.E-03	.00538	1554.8	31.6	4060.3	200.7	95.3
3	1.E-05	.00538	1557.6	40.6	4493.6	200.5	122.8

Pct Std Deviations 51.8 99999.9 62907.3 4474.2 99999.9

Correlation Matrix

1.0000				
-.8435	1.0000			
-.0834	-.1340	1.0000		
.8259	-.9994	.1527	1.0000	
-.8436	1.0000	-.1338	-.9994	1.0000

I	Nspac	Obs	Cal	Pctdif	Wts
1	1	926.0	993.7	-6.8	1
2	1	809.0	993.7	-18.6	1
3	1	1299.0	993.7	30.7	1
4	2	643.0	393.4	63.5	0
5	2	662.0	393.4	68.3	0
6	2	411.0	393.4	4.5	1
7	3	133.0	236.7	-43.8	0
8	3	216.0	236.7	-8.7	1
9	3	113.0	236.7	-52.3	0
10	4	392.0	240.1	63.3	0
11	4	257.0	240.1	7.1	1
12	4	255.0	240.1	6.2	1
13	5	297.0	278.8	6.5	1
14	5	225.0	278.8	-19.3	1
15	6	325.0	323.5	.5	1
16	6	360.0	323.5	11.3	1
17	7	534.0	368.5	44.9	0
18	8	402.0	413.0	-2.7	1

APPENDIX E: REFERENCES

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APPENDIX E-2

EM-16 SURVEY - NO GOOD CREEK AREA, SOUTH RESERVOIR

INTRODUCTION

In September and October of 1979, a VLF-EM survey was performed in the South Reservoir of the Meager Creek project area. The purpose of the survey was to precisely locate and determine properties of the western resistivity anomaly cut-off near No Good Creek. This cut-off takes the form of a marked increase in ground resistivity to the west of No Good Creek and was initially located by the 1974 McPhar resistivity survey and confirmed and extended by the Deep Grid Analysis resistivity survey in 1975.

The survey proposed to evaluate the VLF-EM system as an exploration tool at Meager Creek, as well as to provide additional geologic data such as fault and shear zone locations.

THEORY

The VLF-EM (Very Low Frequency Electromagnetic) system measures the distortion of electromagnetic fields caused by changes in conductivity in the ground. These electromagnetic fields are provided by very low frequency military homing beacons situated around the world. In a flat homogeneously conductive half-space, the VLF-EM system measures a non-varying orientation of the electromagnetic fields produced by the distant antenna. Tilts in the ground surface and existence of anomalous conductivity zones, such as massive sulphide pockets and dykes and water saturated fault gouge zones, within the earth cause the electromagnetic fields to dip into and out of the nominaly horizontal surface of the earth. The VLF-EM method, which measures dips in the electromagnetic fields, allows an interpretation of anomalous conductivity within the earth. More detailed description of the theory and methods of the VLF-EM system can be found in the references listed after this discussion.

SURVEY INSTRUMENTATION AND PROCEDURE

The instrument used in this survey was the Geonics EM-16. This unit provides two measures of the electromagnetic field variation, the so-called in-phase and the out-of-phase or quadrature components. The survey was tuned to the Seattle VLF transmitter south of the survey area and the survey was performed facing west. A total of seven kilometres over five lines was surveyed at twenty-five metre intervals. The lines run approximately east-west but include bearing changes where topography was impassable.

RESULTS AND INTERPRETATION

The location of the survey lines results are presented in Figure E-2. The most notable feature of the survey is a consistent anomaly in the in-phase component that occurs on all five lines. This anomalous zone trends in a north-south direction. It is characterized by negative in-phase components on the sides and a positive or nearly positive in-phase hump centered between the negative flanks. The quadrature component remains relatively neutral except near the positive rise of the in-phase component where it follows the in-phase component.

There are several possible causes for this anomalous feature, all of which could be contributing to the observed anomalies.

The existence of an abrupt change in bedrock resistivity, trending north-south and dipping nearly vertically would produce a signature similar to the one exhibited in this survey (Telford et al, 1977). This could represent a resistivity change related to the western resistivity cut-off. The signature of this anomaly, however, continues on the lower lines 2, 4 and 5 where the bedrock is covered by large thicknesses of overburden. Given the relatively high conductivity of this deep over-overburden as indicated by previous resistivity surveys in the area, it is unlikely that the VLF-EM system could penetrate to bedrock and give a recognizable signature related to a bedrock conductivity contrast.

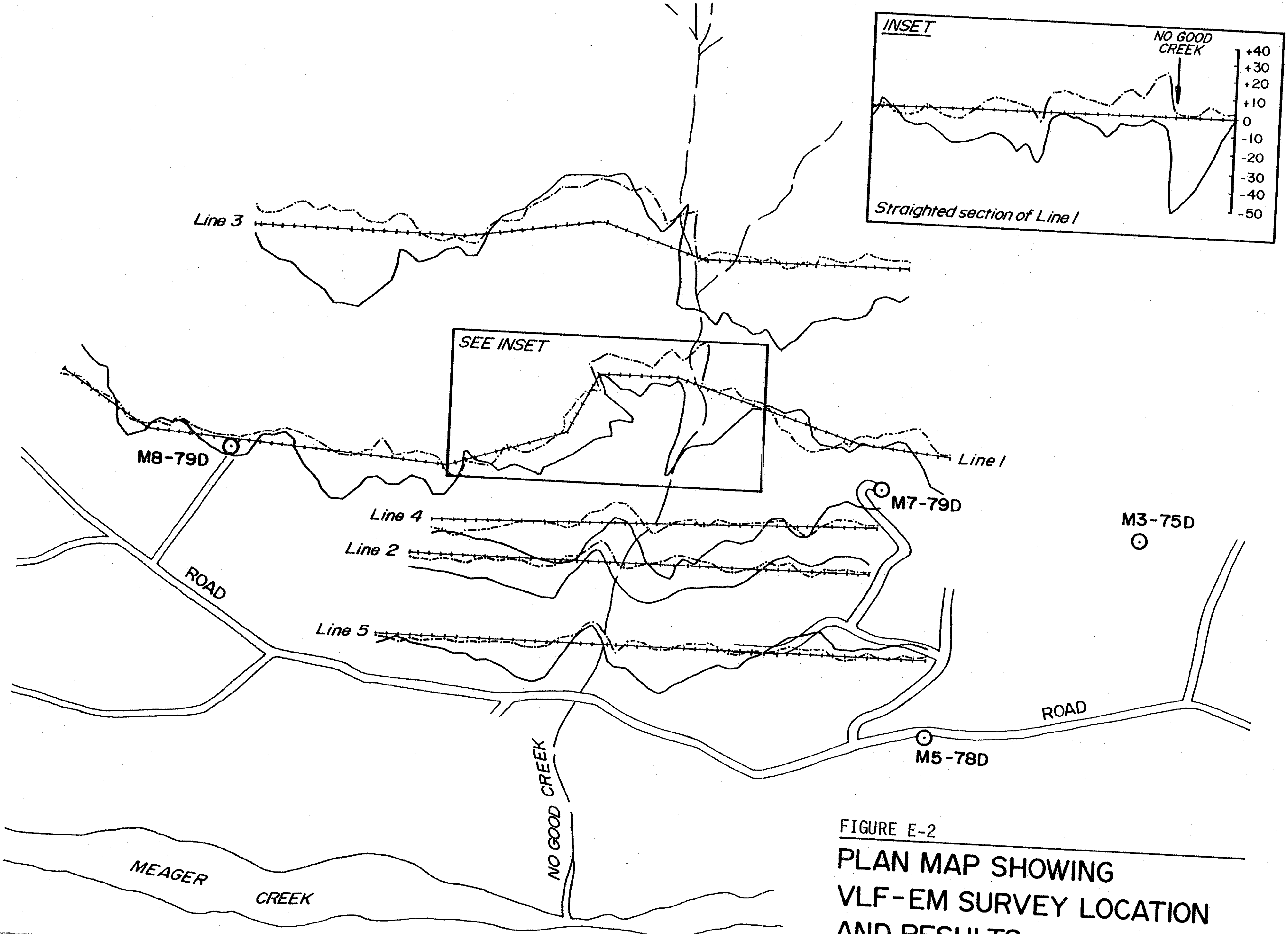

FIGURE E-2

PLAN MAP SHOWING VLF-EM SURVEY LOCATION AND RESULTS

The anomaly signature is similar to that which might be induced by the topographic variations in the area. Topographic variations are amplified by the VLF-EM method when the near surface layer is highly conductive (Patterson and Ronka, 1969). The overburden layers in the area consist of clay rich glacial tills and valley bottom detritus which are likely to be conductive. The general lack of quadrature component indicates that conductive units are causing the anomalies.

Finally, some contribution to the anomaly might be made by conductive saturated sediments in the immediate vicinity of the No Good creekbed.

CONCLUSIONS

The close relationship of the anomalous features of the No Good Creek VLF-EM survey and the local topography of the survey, combined with conductive overburden in the area, suggest that the observed anomaly in the area is induced largely by topography. The existence of a bedrock resistivity contrast and conductive creekbed sediments could be secondary contributors to the observed anomaly. The overburden conductivity in the Meager area, combined with the exceptionally rugged terrain suggest that the VLF-EM exploration is less than ideal for applications at the Meager Creek project.

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